JRS Dynamic Rollover Test

2009 Chevrolet Malibu

Sponsored By:

Automotive Safety Research Institute
Charlottesville, VA.

Vehicle Donated by:
State Farm Insurance Company
Chicago, IL.

Introduction

Center for Injury Research conducted a JRS dynamic rollover test consisting of two rolls of a 2009 Chevrolet Malibu on July 9 and 12, 2010. This test report is organized in sections containing test information, data tables and photographs as follows:

Section 1 – Test Procedures and Summaries

Section 2 – Test Results, Data Tables and Selected Comparison Photographs for Roll 1.

Section 3 – Test Results, Data Tables and Selected Comparison Photographs for Roll 2.

Section 4 – Data Graphs

Section 5 – All Test Photographs

Enclosed with this report is a DVD of the video of both rolls.

2009 Chevrolet Malibu

Executive Summary

The test was a two roll event. The planned difference between the rolls was the pitch of the vehicle; 4.2 degrees in Roll 1 and 9.1 degrees in Roll 2 and the position of the Hybrid III dummy. For Roll 1, the dummy was located “out of position;" leaning towards the passenger side approximately 45°. For Roll 2, the dummy was placed in the nominal seating position. Table 1 describes the impact conditions of each test. Table 2 shows the injury assessment reference values for the low durometer neck that was used.

Table 1 Summary of Test Conditions

Roll	Pitch	Road Speed	Contact Angle	Roll Rate
1	4.2 deg	15.3 mph	151 deg	185 deg/sec
2	9.1 deg	14.9 mph	143 deg	178 deg/sec

Table 2 Lower Neck IARV's for 10% Probability of an AIS ≥ 3 Injury

Neck Type	My (Nm) Flexion	My (Nm) Extension	Mx (Nm)	Axial Fz (N)
Production	380	−156	268	4000
Low Durometer	90-110	−38-−46	59-90	1640-2000
Human/Cadaver	58			1500

In Roll 1, the peak lower neck compressive load was 884 N and the peak lower neck moment was 81 Nm in flexion and 26 Nm in extension. The estimated peak intrusion speed at the top of the A-Pillar was 5.3 mph with an estimated peak crush of 5.4 inches.

In Roll 2, the peak lower neck compressive load was 889 N and the peak lower neck moment was 30 Nm in flexion and 30 Nm in extension. The peak intrusion speed at the top of the A-Pillar was 9.5 mph with a peak crush of 3.6 inches.

1. Test Procedure and Summaries

For each roll of the test, the following steps are performed as necessary:

1. Inspect the test vehicle for prior damage, rust or other factors that might influence the outcome of the test
2. Prepare the test equipment
3. Install and prepare the instrumentation and video cameras
4. Install the test vehicle in test fixture
5. Perform pre-test measurements
6. Photograph the vehicle
7. Conduct the test
8. Perform post test measurements
9. Photograph the vehicle following the test

The windshield of the vehicle was replaced one month prior to the test.

The set up of the test vehicle in the fixture and the instrumentation in the vehicle was the same for Rolls 1 and 2 with the exception of the pitch angle; Roll 1 = 4.2° and Roll 2 = 9.1°.

The test weight of the vehicle was 3,609 pounds. The initial weight of the vehicle was 3,492 pounds. The test roll moment of inertia was approximately 485 lb*ft*sec^2 for a referenced value of 506 lb*ft*sec^2.

The vehicle was suspended on mounts at the rear and at the front in a manner that allowed it to roll freely and be dropped, passenger side (the near side) leading.

The far side string potentiometers used for Roll 2 were disconnected for Roll 1. To record the amount of roof crush during Roll 1, static measurements were taken pre and post test between the string potentiometer housings and their corresponding mounting locations used in Roll 2. The string potentiometers were mounted near the vehicle's longitudinal roll axis and mounted in positions to record the amount of crush at the vehicle's far side (driver's side) A-pillar, roof header and B-Pillar. For Rolls 1 and 2 the near side (passenger's side) string potentiometer functioned normally and recorded dynamic measurements of the roof crush during

both rolls. An instrumented, restrained Hybrid III 50th percentile male test dummy was placed in the driver's seat. The dummy was instrumented with upper and lower neck load cells as well as a triaxial head accelerometer. In addition, seat belt load cells were utilized.

Each roll was conducted with a Hybrid III dummy equipped with a more biofidelic (low durometer) neck and lumbar joint, located in the driver's seat which was positioned in the mid seat position. The dummy was restrained using the vehicle's standard 3 point harness with a non-deployed pre-tensioner. The dummy's head was chalked before the second roll to differentiate between impact marks during the two tests. To make the Hybrid III dummy more biofidelic, the two cables in the lower spine of the dummy were removed. The upper neck mounting block was replaced with a block that increased the neck angle forward 30 degrees from the nominal position.

For the first roll the dummy was tethered "out of position" with a light wire that electronically disconnected at approximately 90° of roll. The "out of position" location of the dummy was found by rotating the vehicle by 90° toward the passenger side. This orientation simulated the dummy accelerating toward the passenger side door at 1 g. The driver's side curtain airbag was deployed at approximately 38° of roll. For the second roll the dummy was placed in the nominal seating position and the deployed side curtain airbag was removed.

Six vertical and two lateral load cells were placed in the moving roadway to record the impact characteristics of the test.

Two string potentiometers were placed on the fixture support towers to record vehicle vertical motion characteristics during the test. One string potentiometer was located in the front drop tower and the other was located in the rear drop tower.

A roll encoder was placed on the cable pulley which pulls the moving roadway to record the roadway velocity throughout the test. In addition, a roll rate sensor was placed inside the vehicle.

The equipment used in the conduct of this test is listed in Table 3 and the test vehicle identification data is shown in Table 4 below.

Table 3 Equipment and Instrumentation

Item	MFR./Model
String Potentiometer – Driver's Side A-Pillar	Space Age Control – 301432
String Potentiometer – Driver's Side B-Pillar	Space Age Control – 301432
String Potentiometer – Roof Header	Space Age Control – 301432
String Potentiometer – Passenger's Side A-Pillar	Space Age Control – 301432
String Potentiometer – Front Fixture Support Tower	Space Age Control – 4332-01
String Potentiometer – Rear Fixture Support Tower	Space Age Control – 4332-01
Upper Neck Load Cell	RA Denton 1716A
Lower Neck Load Cell	RA Denton 1794A
Triaxial Head Accelerometer	Endevco, 7264C-2KTZ-2-240
Belt Load Cell - Lap	RADenton 3255
Belt Load Cell - Torso	RADenton 3255
Roll Rate Sensor	DTS ARS
Hybrid III, 50th Percentile Male	Denton 50th Male
Vertical Load Cell 1	Transducer Techniques, SWP-20k – 173372
Vertical Load Cell 2	Transducer Techniques, SWP-20k – 176138
Vertical Load Cell 3	Transducer Techniques, SWP-20k – 176139
Vertical Load Cell 4	Transducer Techniques, SWP-20k – 176140
Vertical Load Cell 5	Transducer Techniques, SWP-20k – 176141
Vertical Load Cell 6	Transducer Techniques, SWP-20k – 176142
Lateral Load Cell 1	Transducer Techniques, DSM-8k – 149806
Lateral Load Cell 2	Transducer Techniques, DSM-8k – 149807
Roadway Velocity Roll Encoder	Contelec – RSC 2201 236 111 106
Vehicle Data Acquisition System	Diversified Technical Systems, TDAS PRO SIM
Roadway Data Acquisition System	Diversified Technical Systems, TDAS PRO SIM
JRS Fixture Acquisition System	Measurement Computing, USB – 1608FS

Table 4 General Test Vehicle Data Test Vehicle: 2009 Chevrolet Malibu

Test Vehicle Information:	
Manufacturer: Chevrolet	VIN: 1G1ZK57799F115412
Gross Weight: 4,642 lb	Curb Weight: 3,642 lb
Sunroof: Yes	2WD/4WD: 2WD
Equivalent Years: 2008- Present	Body Type: 4 Door

2. Test Results, Data Tables and Selected Comparison Photographs for Roll 1.

The results of the first roll of the JRS Dynamic Rollover Test are presented in this section. In the roll, the vehicle dropped as planned and contacted the vehicle's roof structure.

Roll 1 – 07/09/2010

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)	Peak Velocity (mph)
Sum of Vertical Load Cells (near side contact)	9,433 lb		
Sum of Vertical Load Cells (far side contact)	22,258 lb		
Sum of Lateral Load Cells (near side contact)	1,168 lb		
Sum of Lateral Load Cells (far side contact)	2,056 lb		
Driver's Side A-Pillar String Potentiometer*	-5.4 in	3.6	5.3
Driver's Side B-Pillar String Potentiometer*	-5.0 in	3.1	5.7
Roof Header String Potentiometer*	-2.5 in	1	3.1
Passenger's Side A-Pillar String Potentiometer	-0.4 in	0.1	1.3

*Peak Value and Peak Velocity estimated.

Instrument	Maximum Value	Minimum Value
Lap Belt Load	245 lb	-3 lb
Shoulder Belt Load	171 lb	-7 lb
Dummy Head Acceleration Ax	25 g	-32 g
Dummy Head Acceleration Ay	24 g	-7 g
Dummy Head Acceleration Az	9 g	-51 g
Lower Neck Load Cell Fx	1,204 N	-7 N
Lower Neck Load Cell Fy	197 N	-302 N
Lower Neck Load Cell Fz	167 N	-884 N
Lower Neck Load Cell Mx	8 Nm	-38 Nm
Lower Neck Load Cell My	81 Nm	-26 Nm
Upper Neck Load Cell Fz	167 N	-2,464 N
HIC	81	N/A

The vertical load cells mounted on the roadway platform show the near and far side impacts. The vehicle struck the roadway on the near side at approximately 1.71 seconds. The entire roll sequence was completed by approximately 2.03 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 2.2 inches and the rear dropped 5.3 inches prior to initial touch down. The vehicle was pitched at 4.2 degrees at contact.

The roll encoder located on the cable pulley shows the roadway velocity throughout the roll. The roadway was traveling at 15.3 mph at contact. A roll rate sensor in the vehicle was used to determine the roll angle and rate at impact. The roll angle of the vehicle was 151 degrees and the roll rate was 185 degrees per second at the roadway impact.

During the first roll the windshield and driver side front laminated window fractured. A small buckle type deformation occurred in the far side C-pillar. The tempered glass from the sunroof shattered completely.

A pull test was conducted on the driver side doors of the vehicle after the first roll. The front door opened partially, but remained jammed, with 30 lb of force pulling at the door handle. The force was increased to 70 lb and the door remained stuck. It was clear that the top rear corner of the front door was pinned behind the top front corner of the rear door. The rear door took about 5 lb of force to open. The front door was able to open fully after the rear door was opened.

Roll 1 Comparison Photographs

Figure 1: Vehicle Pre Roll 1

Figure 2: Vehicle Post Roll 1

3. Test Results, Data Tables and Selected Comparison Photographs for Roll 2.

The results of the second roll of the JRS Dynamic Rollover Test are presented in this section. In the roll, the vehicle dropped as planned and contacted the vehicle's roof structure.

Roll 2 – 07/12/2010

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)	Peak Velocity (mph)
Sum of Vertical Load Cells (near side contact)	7,645 lb		
Sum of Vertical Load Cells (far side contact)	27,214 lb		
Sum of Lateral Load Cells (near side contact)	967 lb		
Sum of Lateral Load Cells (far side contact)	1,456 lb		
Driver's Side A-Pillar String Potentiometer	-3.6	-1.4	-9.5
Driver's Side B-Pillar String Potentiometer	-2.0	-0.4	-5.1
Roof Header String Potentiometer	-2.5	-0.9	-5.0
Passenger's Side A-Pillar String Potentiometer	-1.2	-0.2	-2.0

Instrument	Maximum Value	Minimum Value
Lap Belt Load	299 lb	-3 lb
Shoulder Belt Load	157 lb	0 lb
Dummy Head Acceleration Ax	13 g	-8 g
Dummy Head Acceleration Ay	48 g	-5 g
Dummy Head Acceleration Az	33 g	-39 g
Lower Neck Load Cell Fx	1,035 N	-311 N
Lower Neck Load Cell Fy	531 N	-118 N
Lower Neck Load Cell Fz	683 N	-889 N
Lower Neck Load Cell Mx	18 Nm	-39 Nm
Lower Neck Load Cell My	30 Nm	-30 Nm
Upper Neck Load Cell Fz	1,199 N	-2,071 N
HIC	75	N/A

The vertical load cells mounted on the roadway platform show the near and far side impacts. The vehicle struck the roadway on the near side at approximately 1.74 seconds. The entire roll sequence was completed by approximately 2.05 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 2.4 inches and the rear dropped 5.9 inches prior to initial touch down. The vehicle was pitched at 9.1 degrees at contact.

The roll encoder located on the cable pulley shows the roadway velocity throughout the roll. The roadway was traveling at 14.9 mph at contact. A roll rate sensor in the vehicle was used to determine the roll angle and roll rate at impact. The roll angle of the vehicle was 143 degrees and the roll rate was 178 degrees per second at the roadway impact.

During the second roll the windshield and driver side front window fractured further. The rear of the front driver side door was tucked behind the front of the rear driver side door and was unable to be opened. The rear door opened with approximately 5 lb of force. After the rear door was opened, the front door also opened with approximately 5 lb of force.

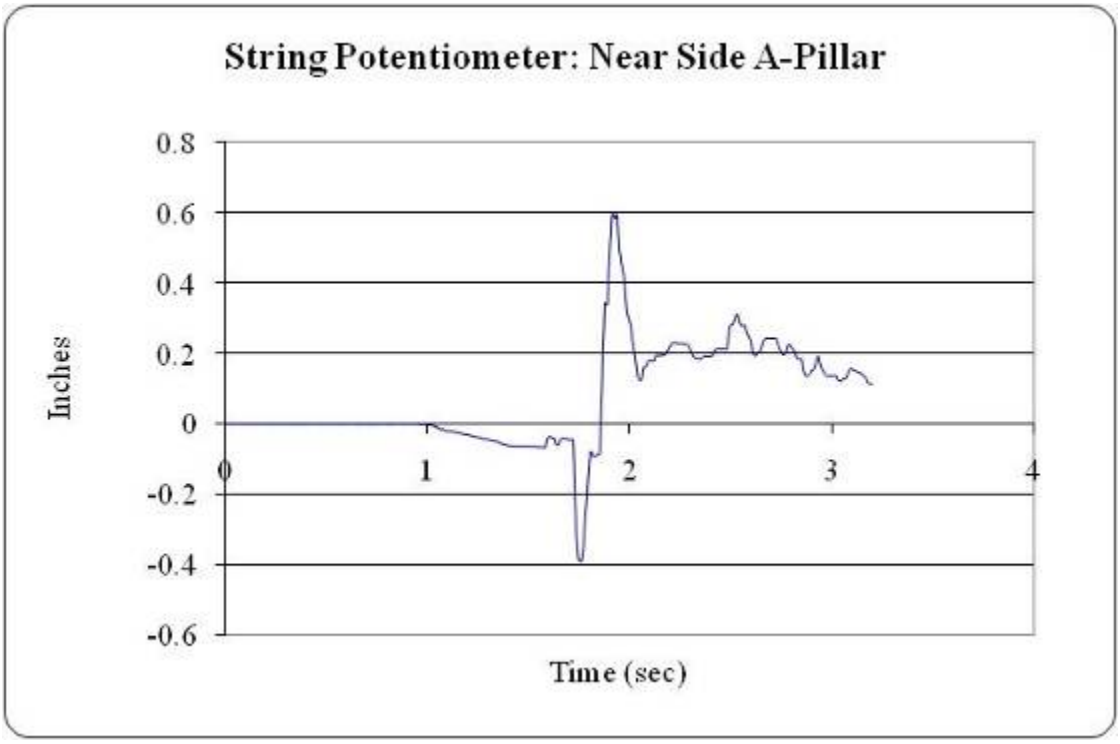
Roll 2 Comparison Photographs

Figure 3: Vehicle Pre Roll 2

Figure 4: Vehicle Post Roll 2

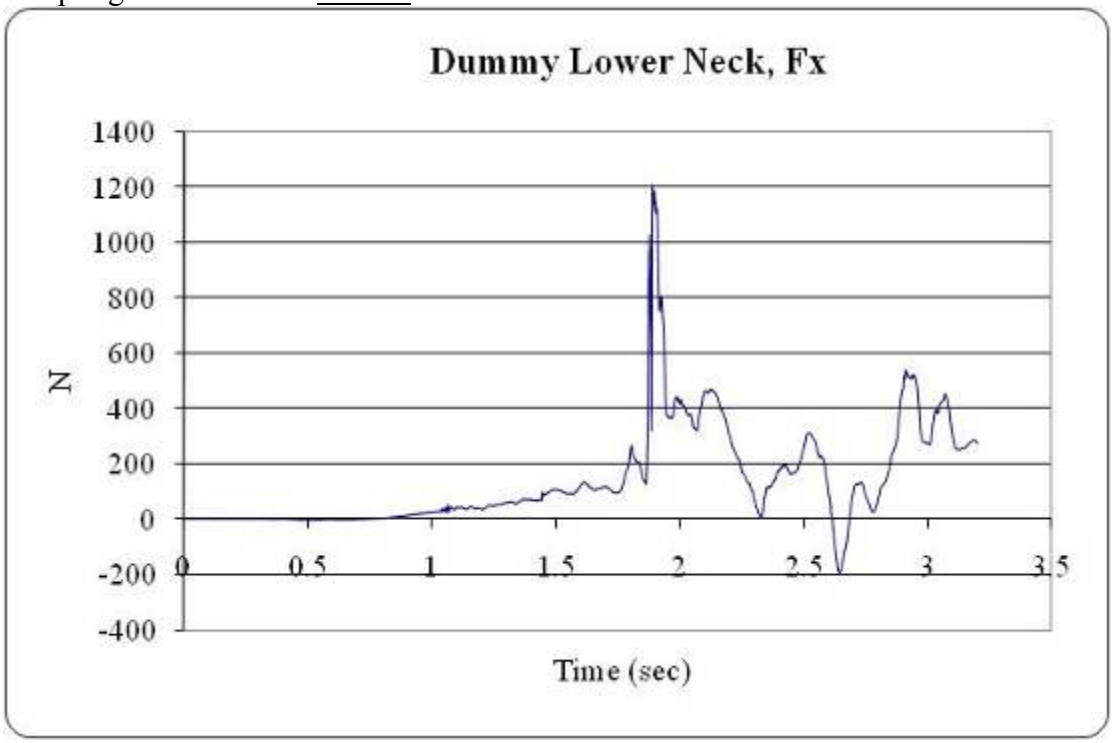
4. Data Graphs

Roll 1 Data Plots – 07/09/2010



Plot 1: String Potentiometer Passenger's Side A-Pillar Displacement v. Time

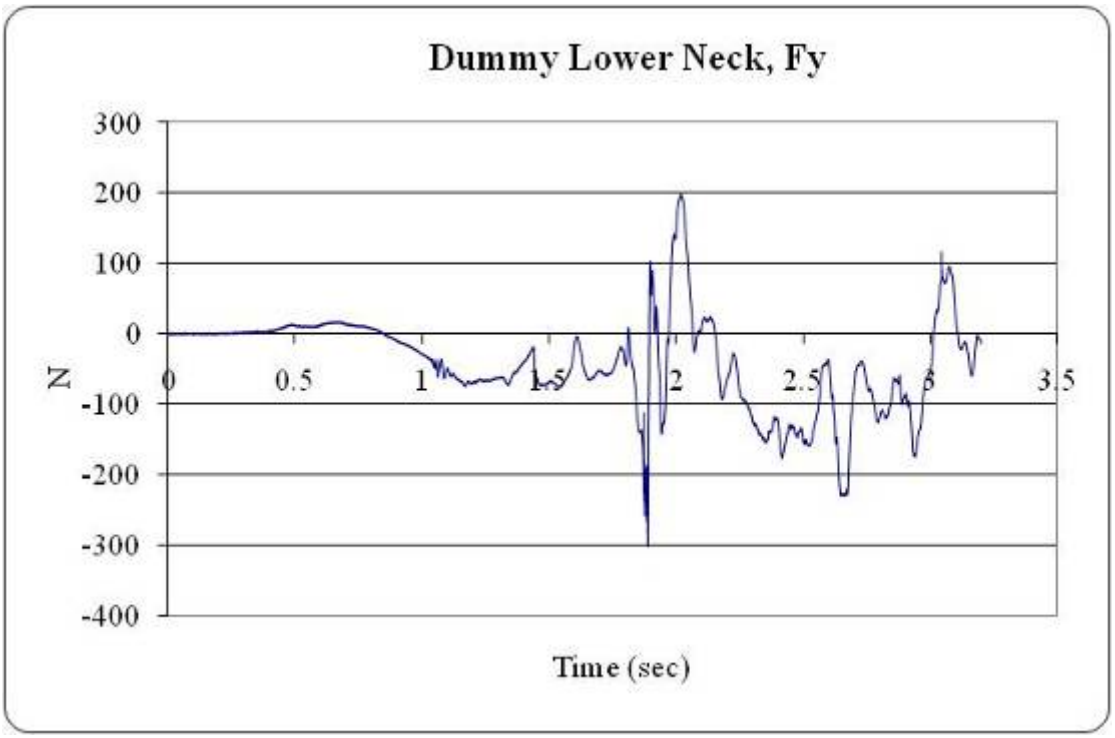
Data Sampling Rate: 10 kHz



Plot 2: Lower Neck Load, Fx, v. Time

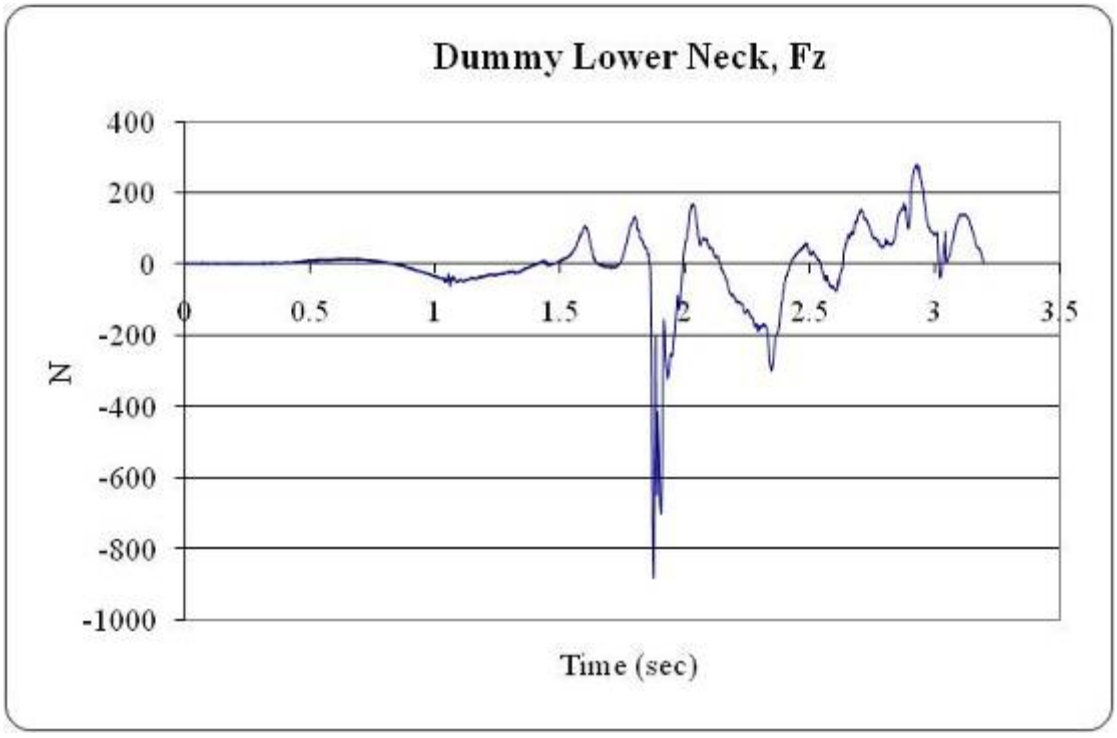
Data Sampling Rate: 10 kHz

Roll 1



Plot 3: Lower Neck Load, Fy, v. Time

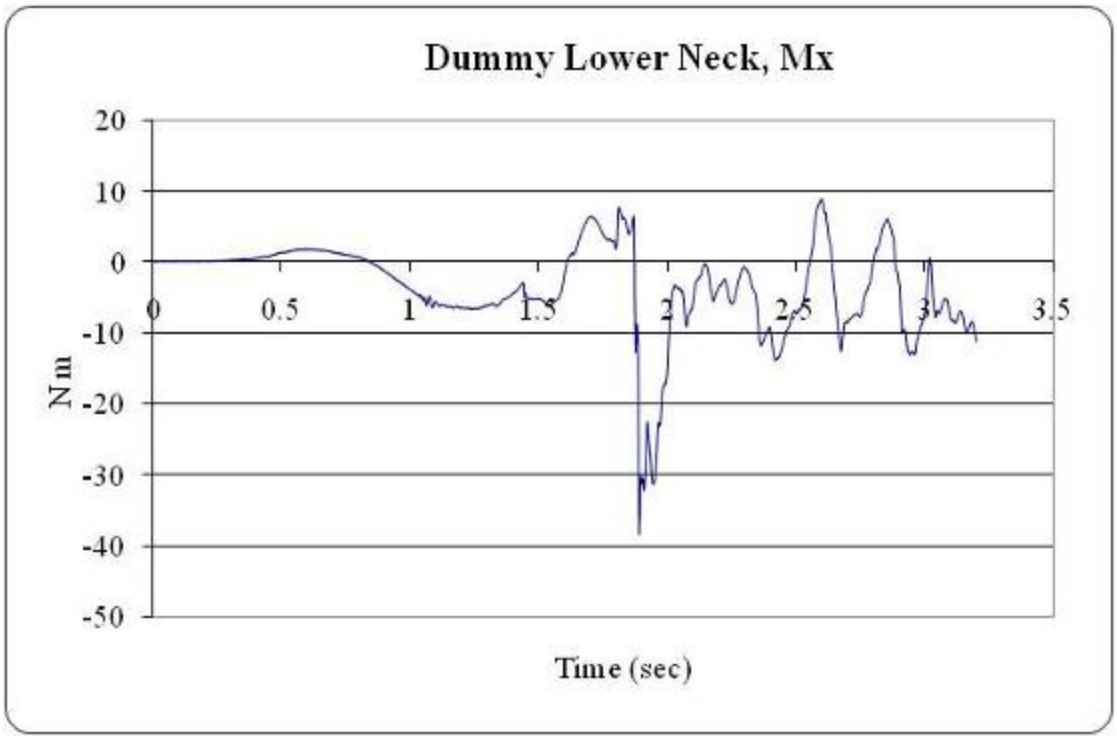
Data Sampling Rate: 10 kHz



Plot 4: Lower Neck Load, Fz, v. Time

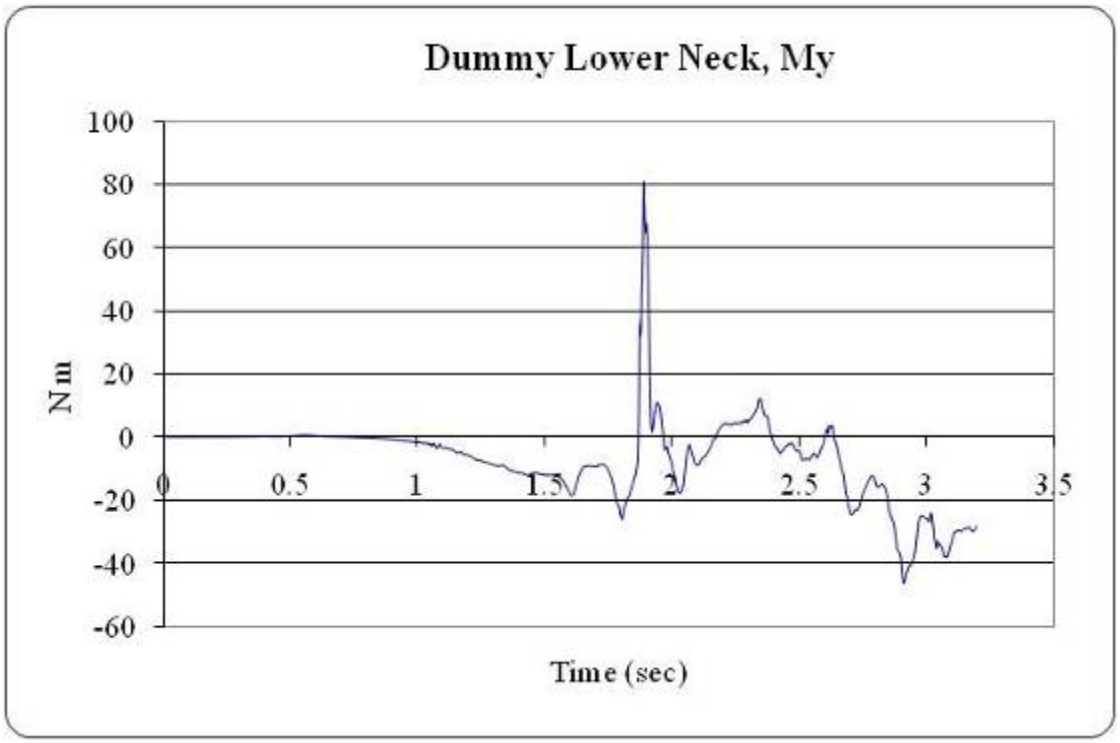
Data Sampling Rate: 10 kHz

Roll 1



Plot 5: Lower Neck Load, Mx, v. Time

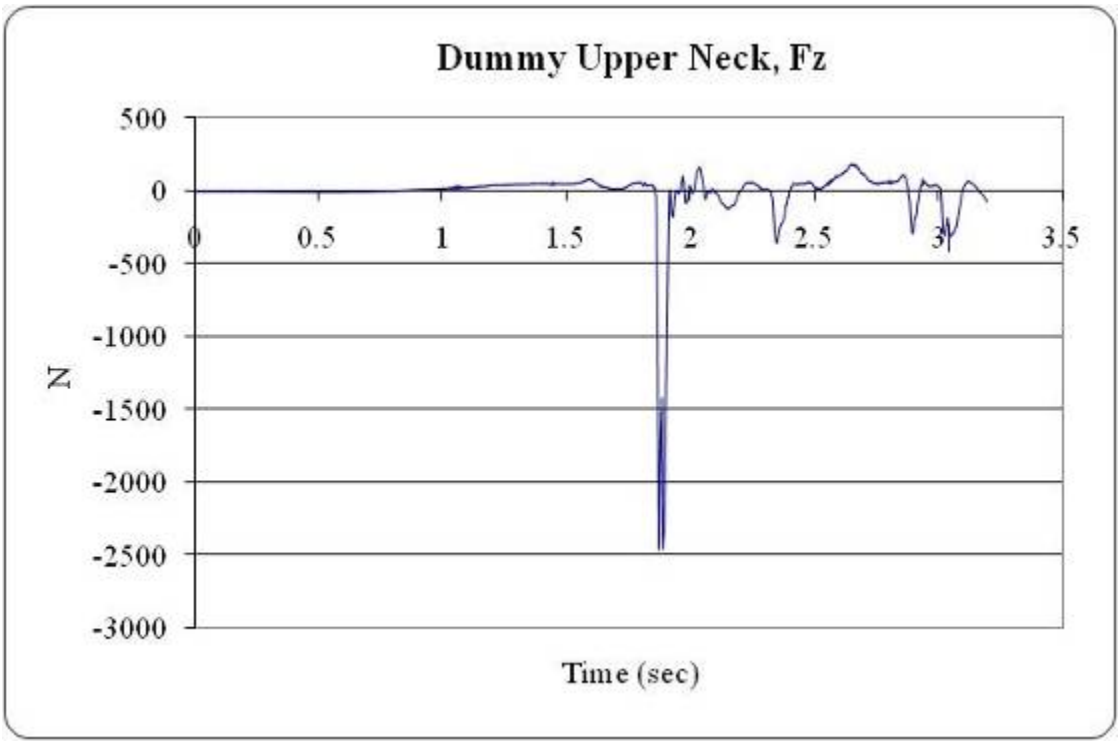
Data Sampling Rate: 10 kHz



Plot 6: Lower Neck Load, My, v. Time

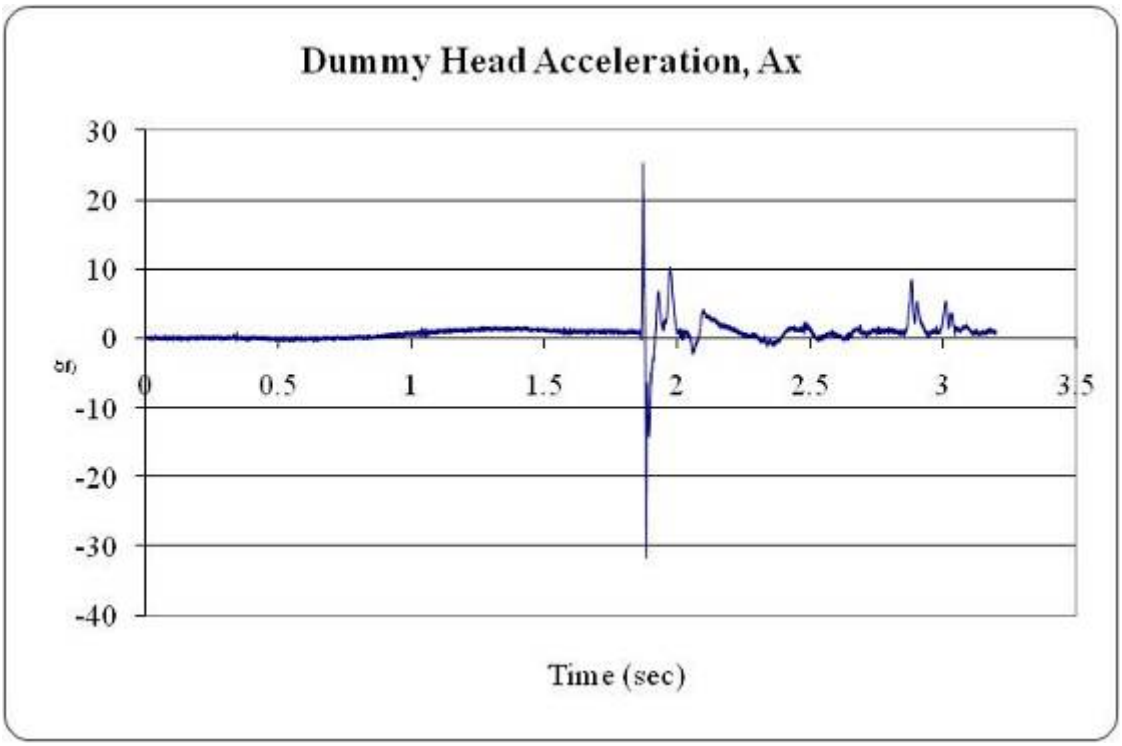
Data Sampling Rate: 10 kHz

Roll 1



Plot 7: Upper Neck Load, Fz, v. Time

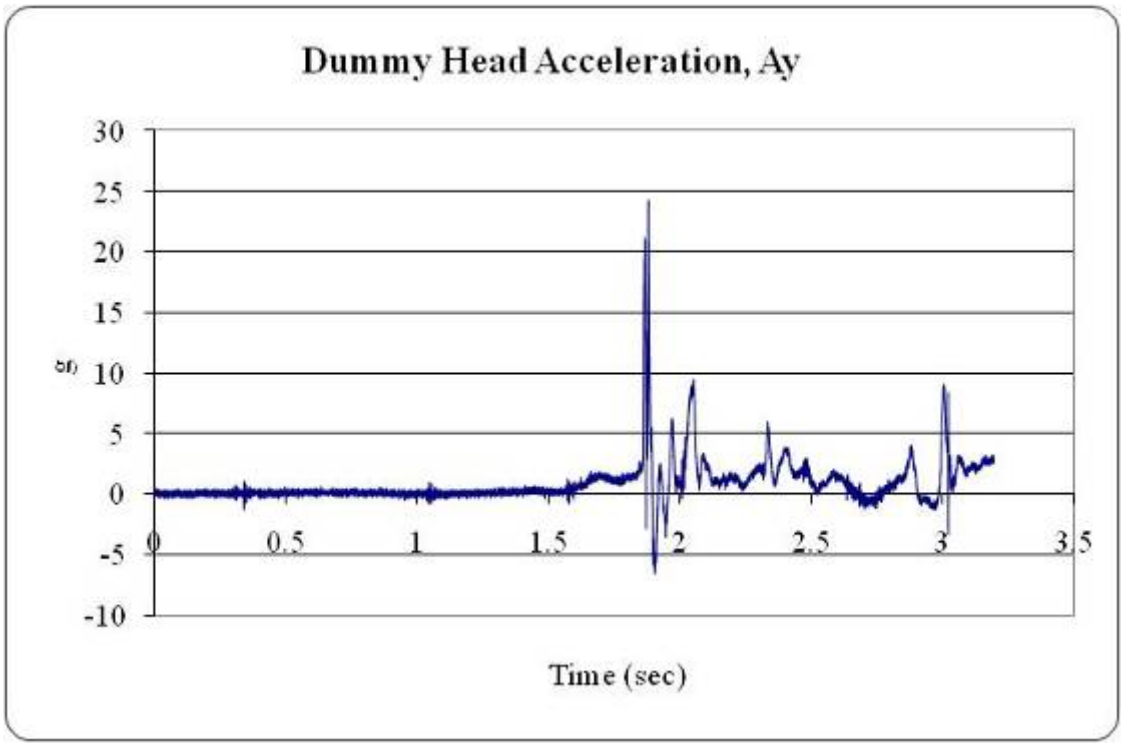
Data Sampling Rate: 10 kHz



Plot 8: Head Acceleration, Ax, vs. Time

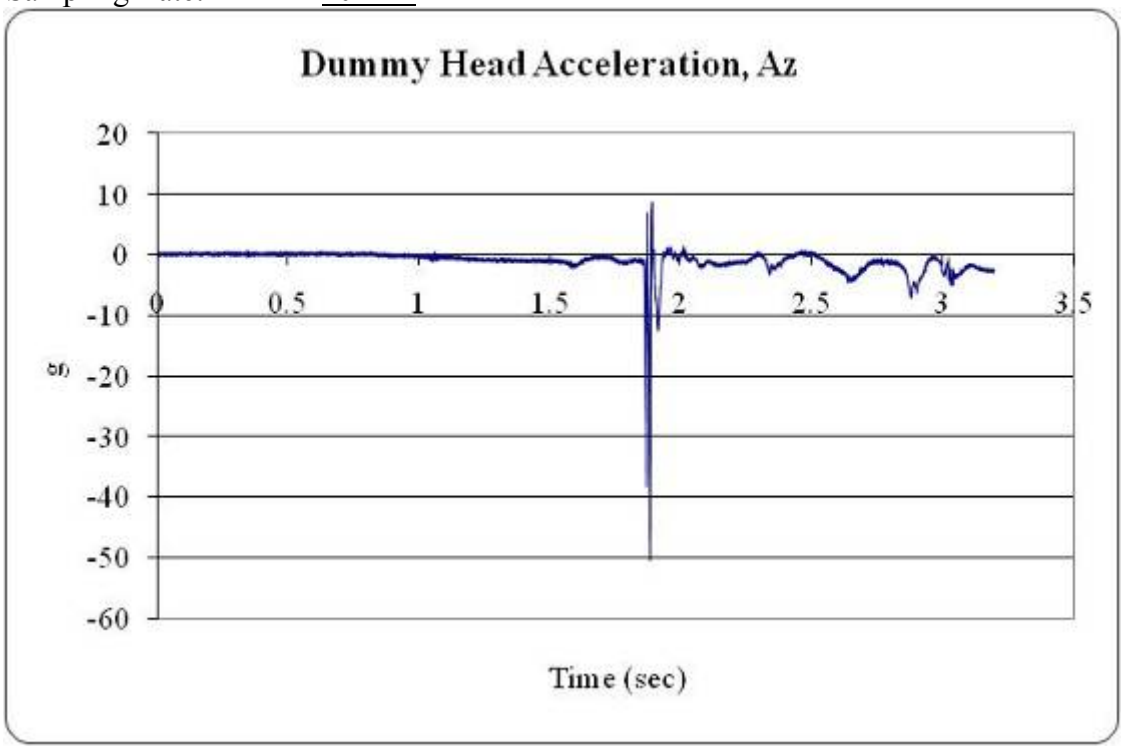
Data Sampling Rate: 10 kHz

Roll 1



Plot 9: Head Acceleration, Ay, vs. Time

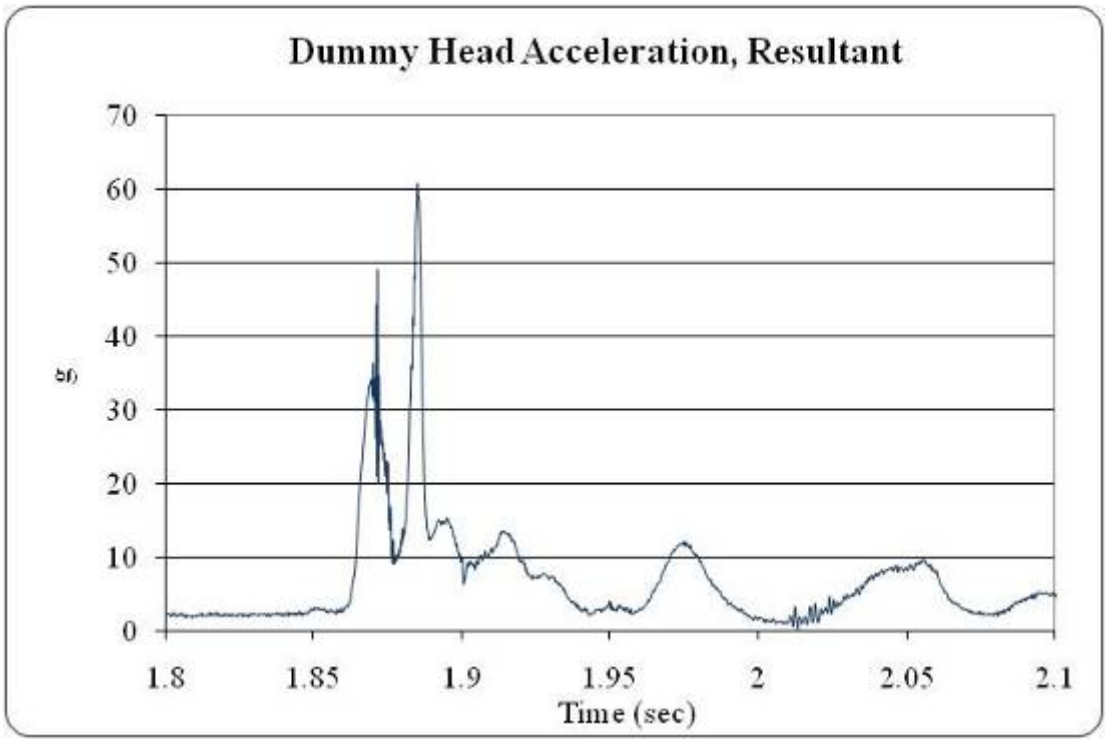
Data Sampling Rate: 10 kHz



Plot 10: Head Acceleration, Az, vs. Time

Data Sampling Rate: 10 kHz

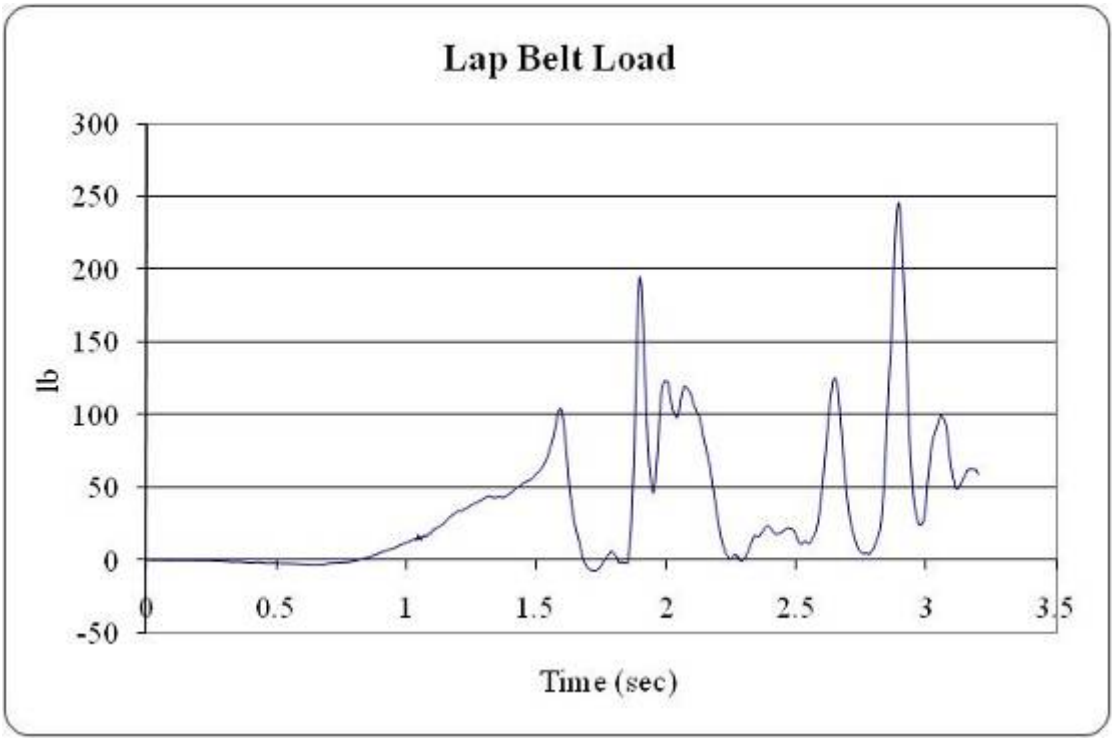
Roll 1



Plot 11: Resultant Head Acceleration vs. Time

HIC = 81

Data Sampling Rate: 10 kHz

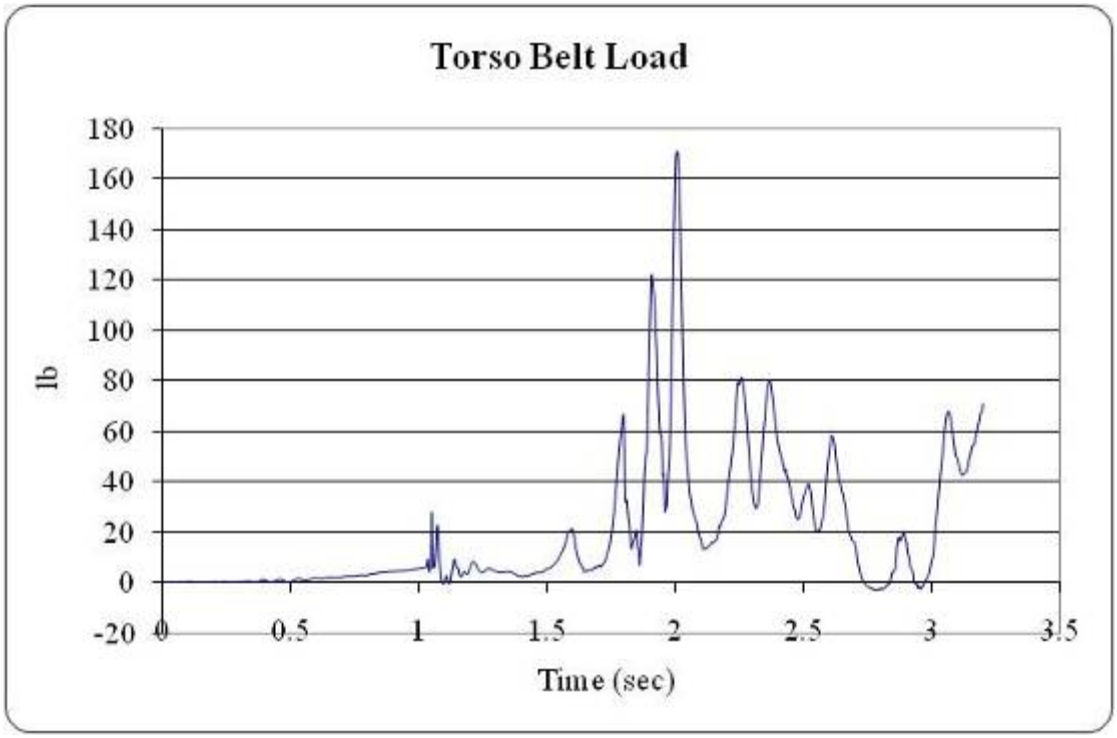


Plot 12: Lap Belt Load* vs. Time

*Measured on one side of the belt

Data Sampling Rate: 10 kHz

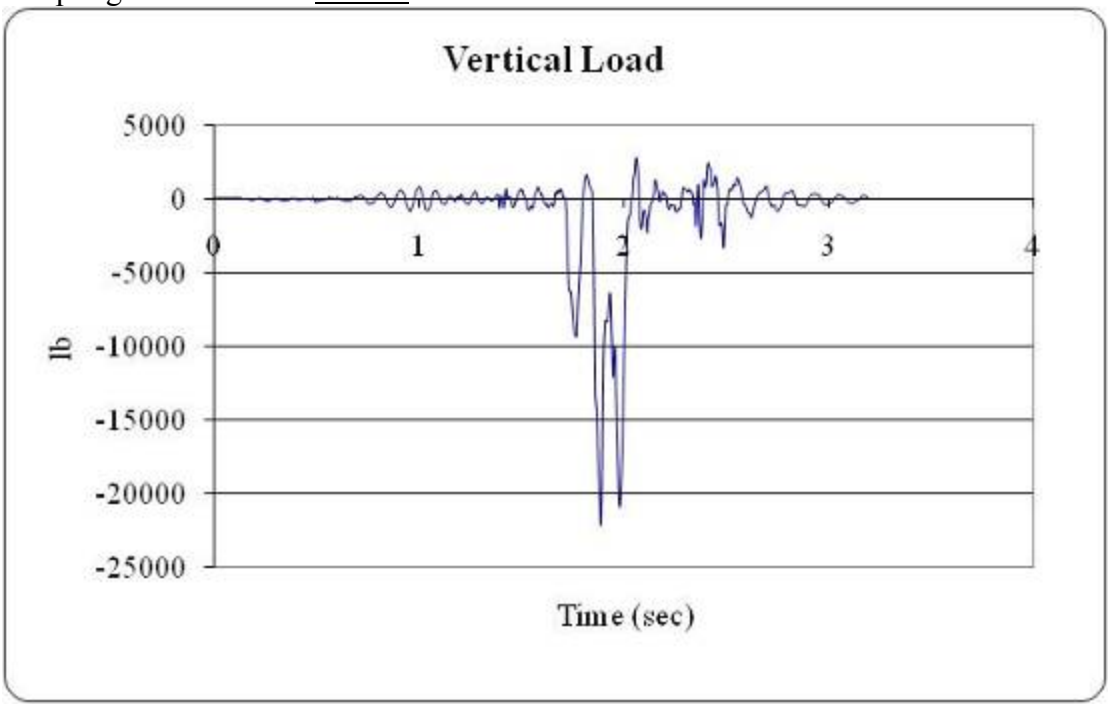
Roll 1



Plot 13: Torso Belt Load* vs. Time

*Measured on one side of the belt

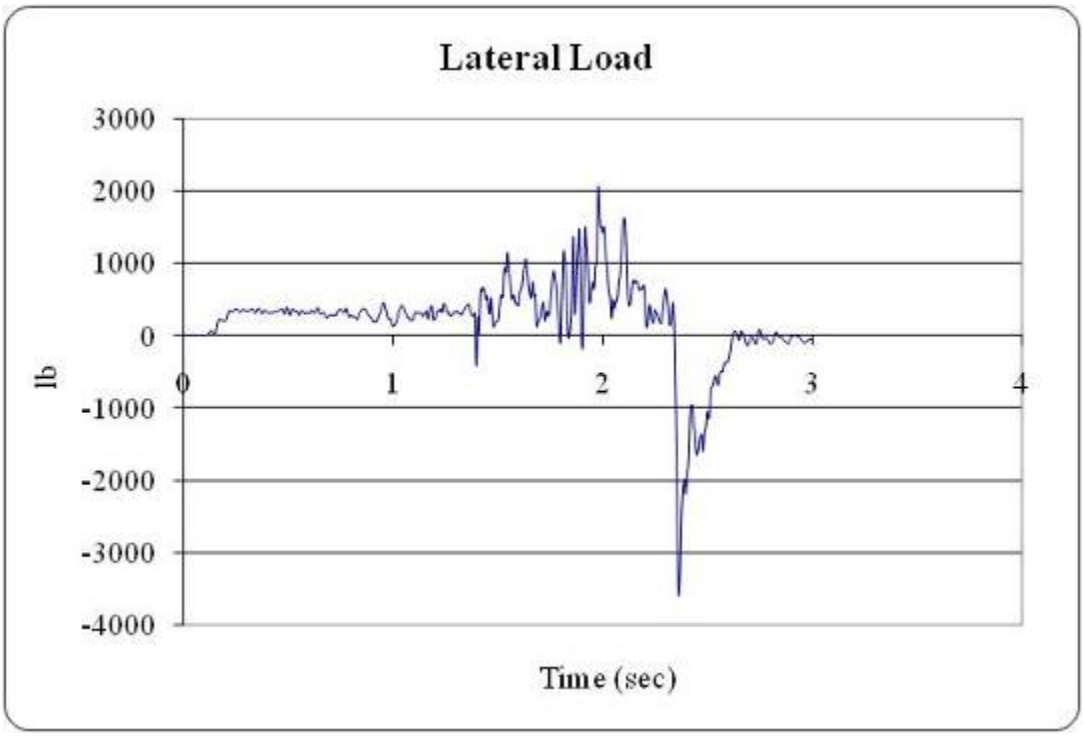
Data Sampling Rate: 10 kHz



Plot 14: Total Vertical Load v. Time

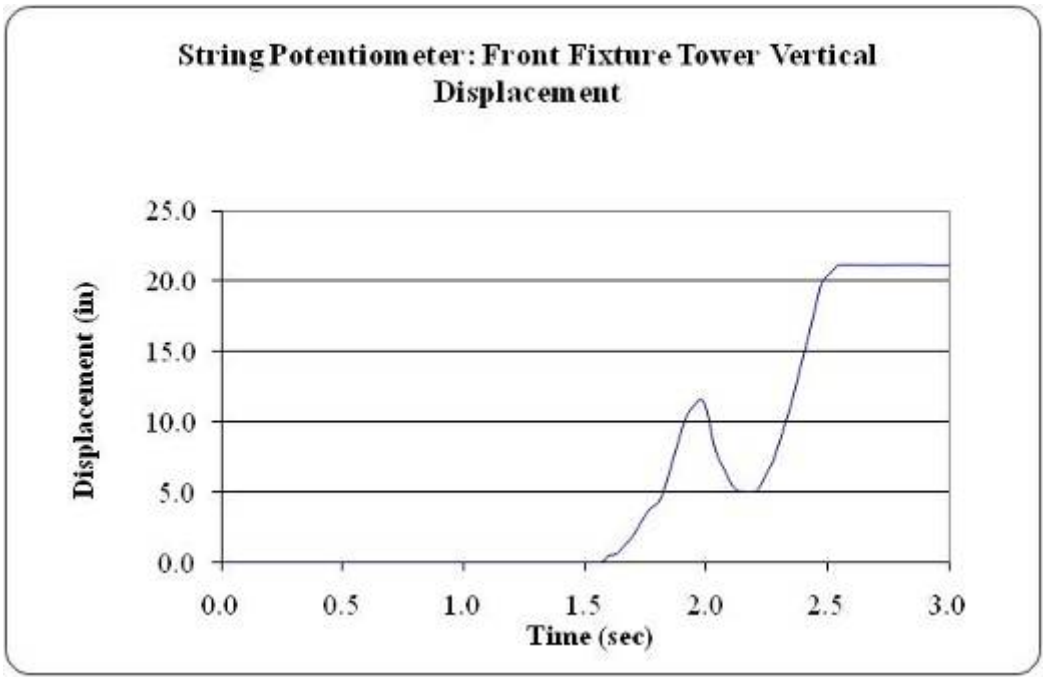
Data Sampling Rate: 10 kHz

Roll 1



Plot 15: Total Lateral Load v. Time

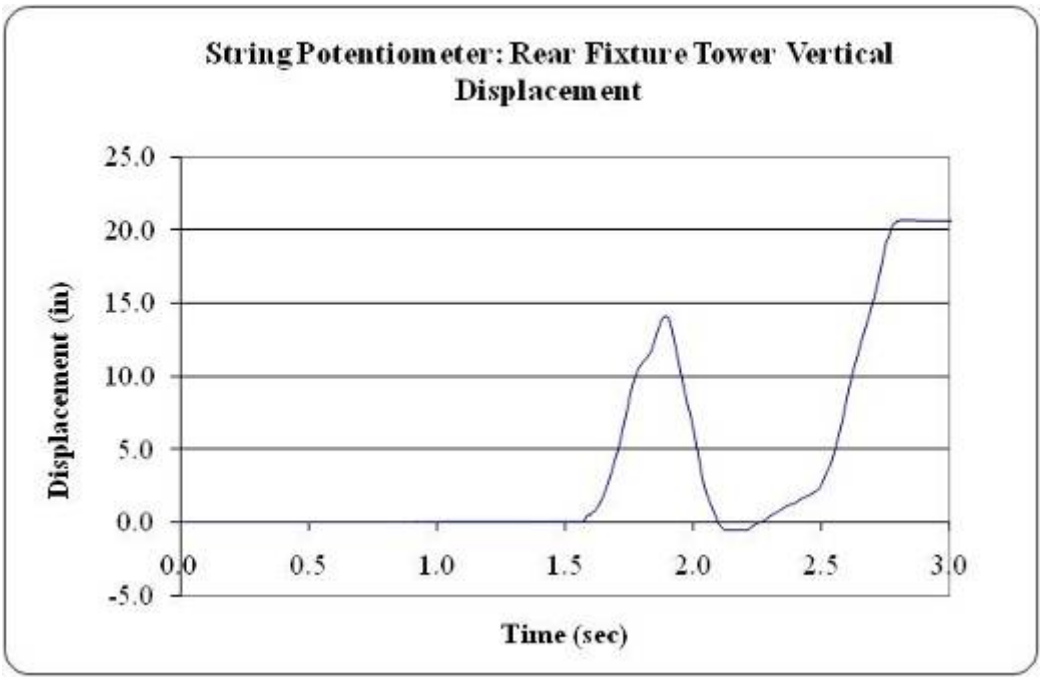
Data Sampling Rate: 10 kHz



Plot 16: String Potentiometer Front Fixture Support Tower Displacement vs. Time

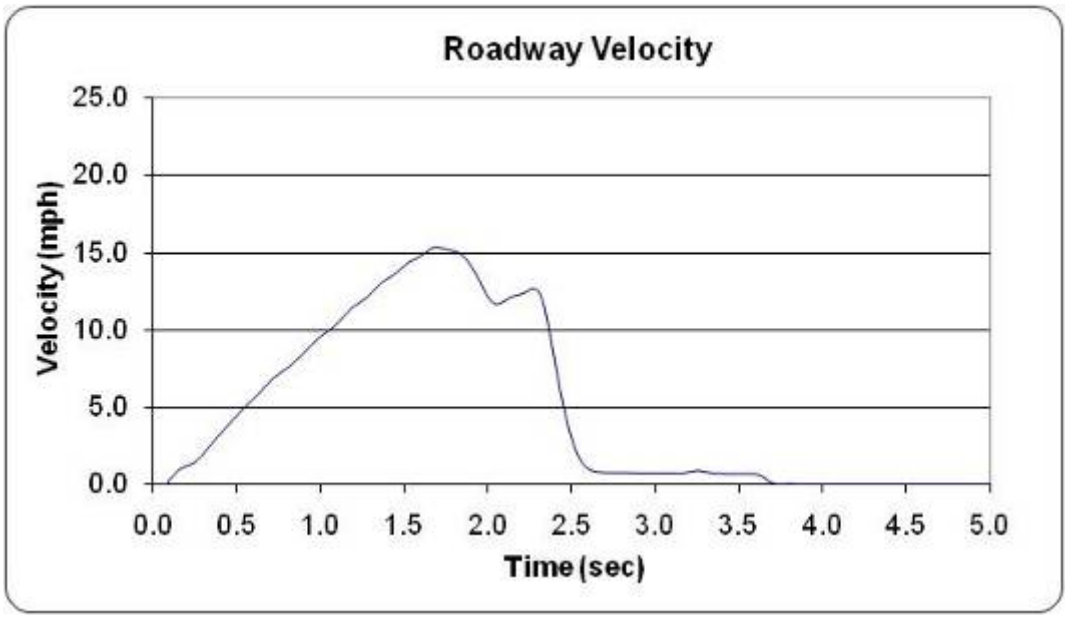
Data Sampling Rate: 1 kHz

Roll 1



Plot 17: String Potentiometer Rear Fixture Support Tower Displacement vs. Time

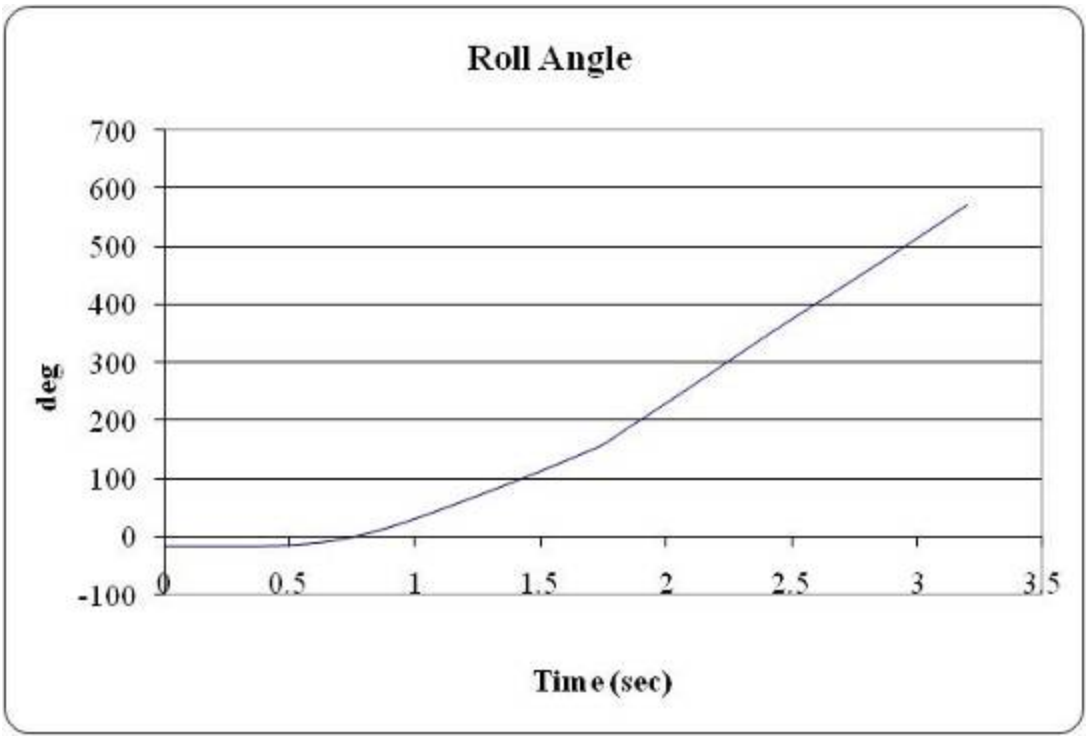
Data Sampling Rate: 1 kHz



Plot 18: Roll Encoder on Roadway Velocity vs. Time

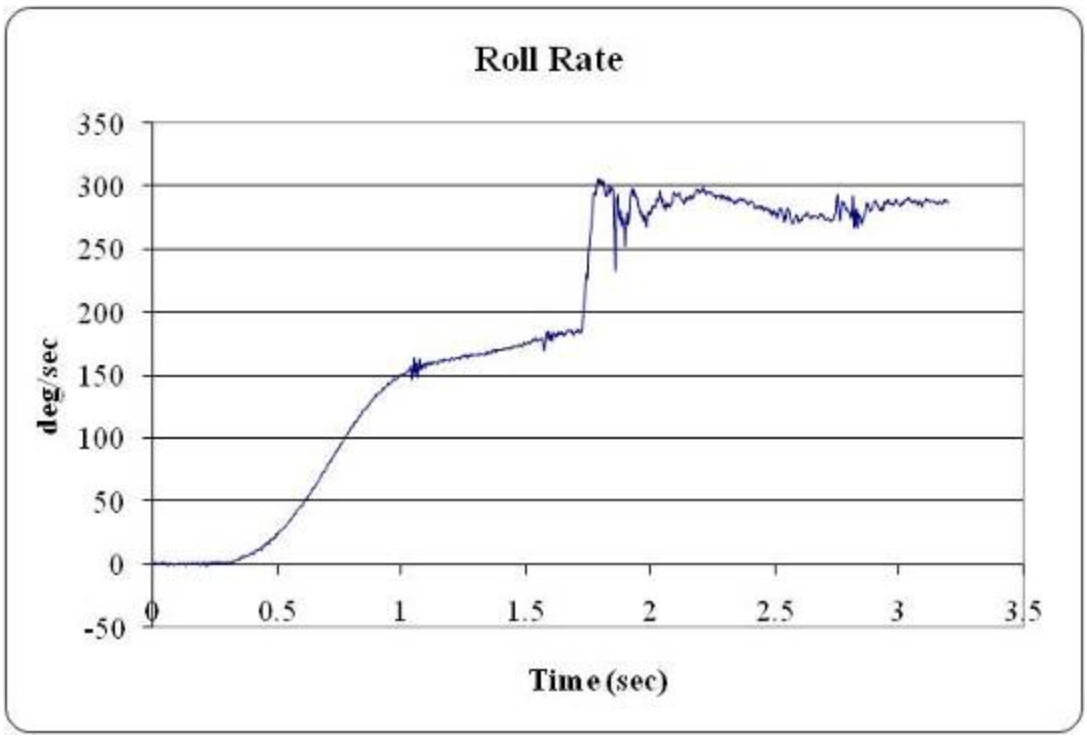
Data Sampling Rate: 1 kHz

Roll 1



Plot 19: Roll Angle vs. Time

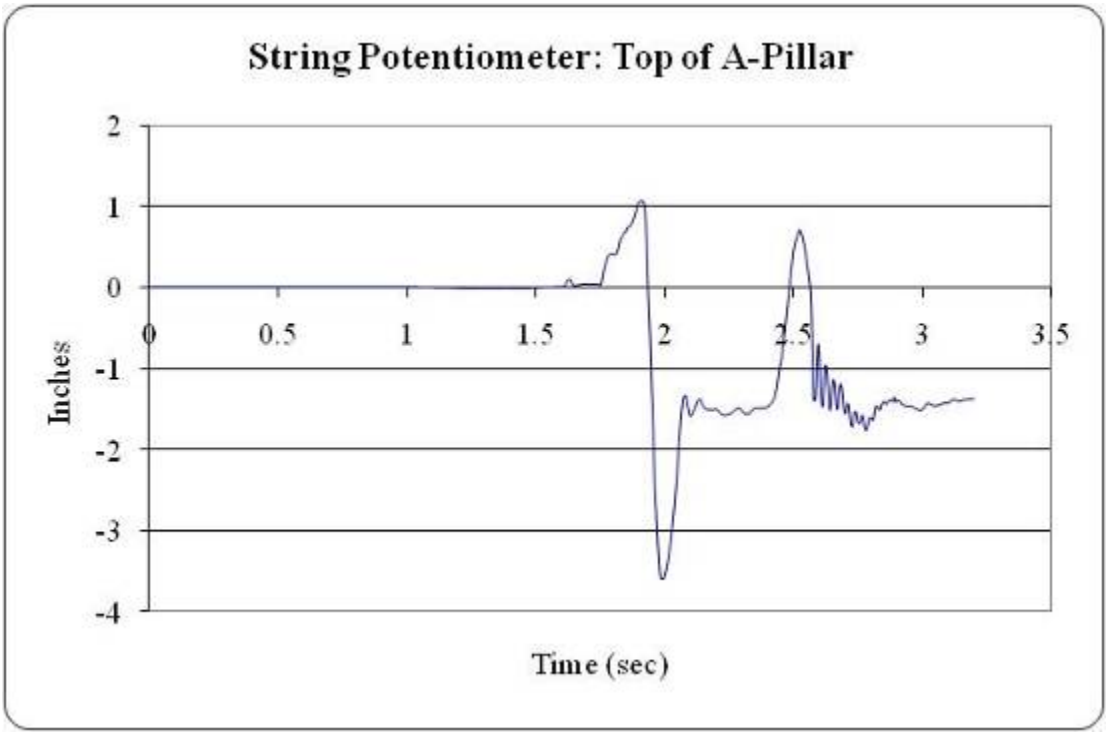
Data Sampling Rate: 10 kHz



Plot 20: Roll Rate vs. Time

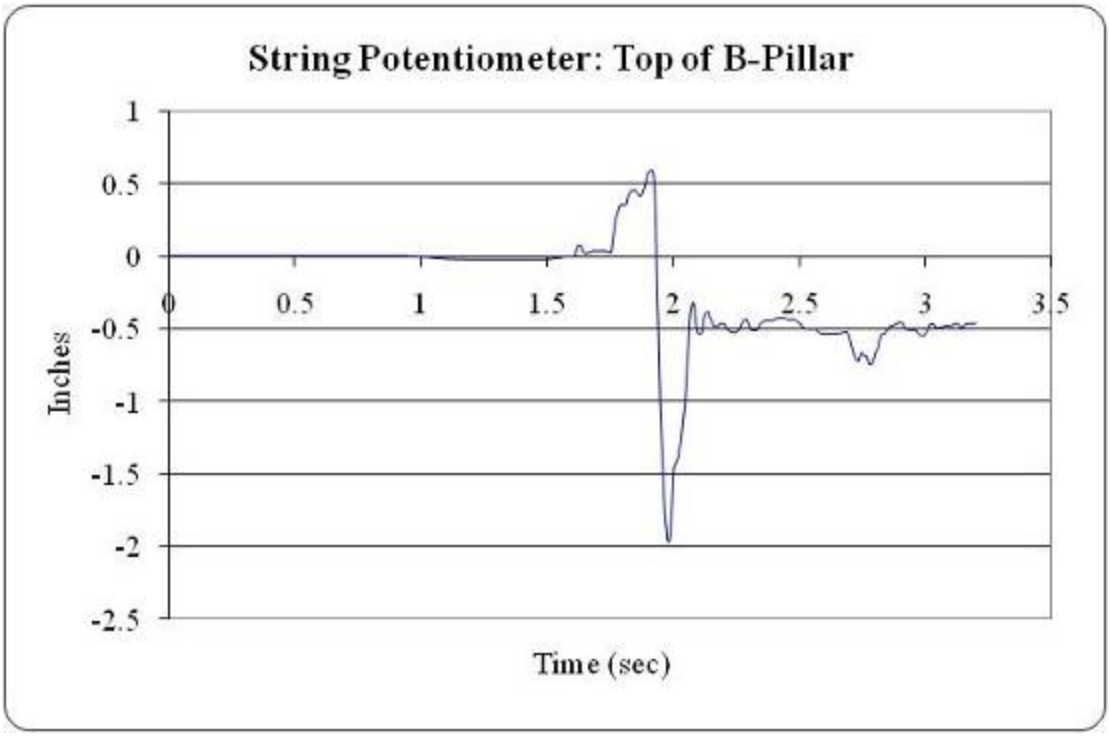
Data Sampling Rate: 10 kHz

Roll 2 Data Plots – 07/12/2010



Plot 21: String Potentiometer Driver's Side A-Pillar Displacement v. Time

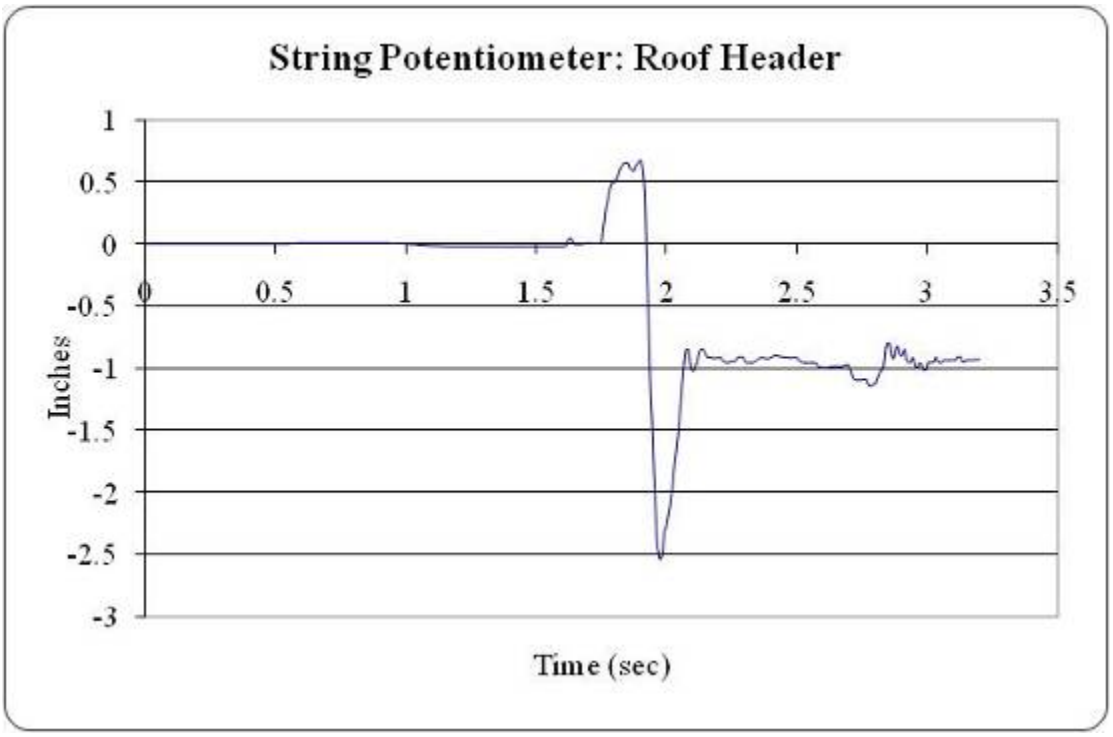
Data Sampling Rate: 10 kHz



Plot 22: String Potentiometer Driver's Side B-Pillar Displacement v. Time

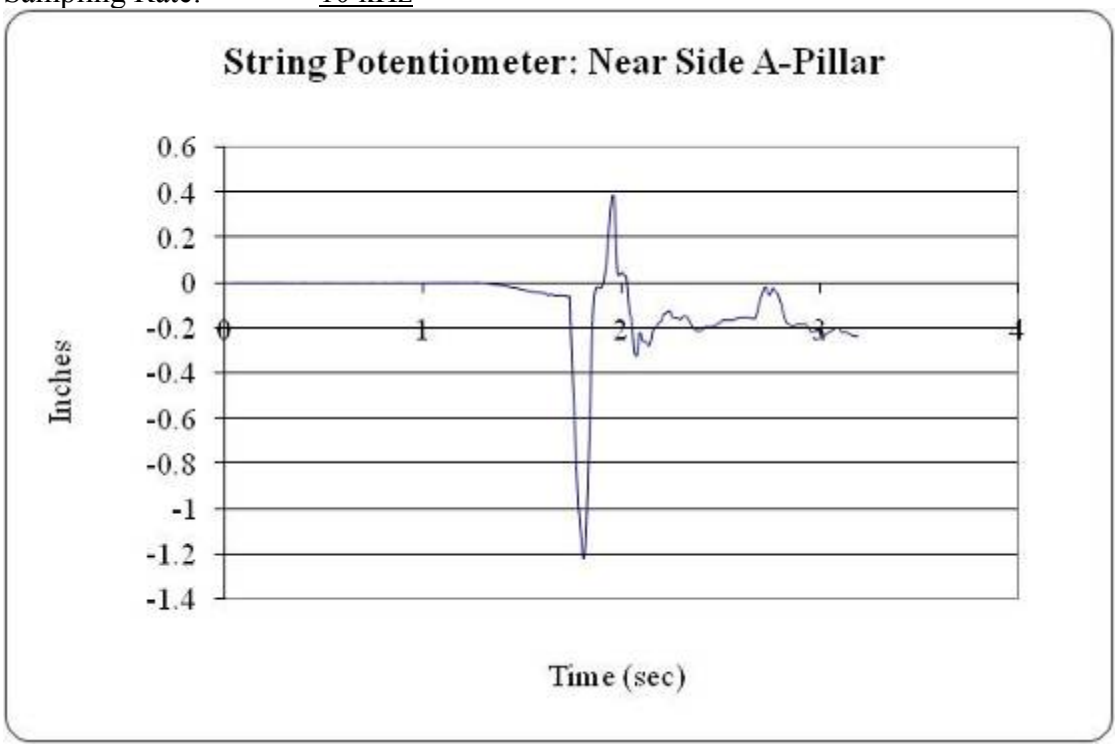
Data Sampling Rate: 10 kHz

Roll 2



Plot 23: String Potentiometer Driver's Side Roof Header Displacement v. Time

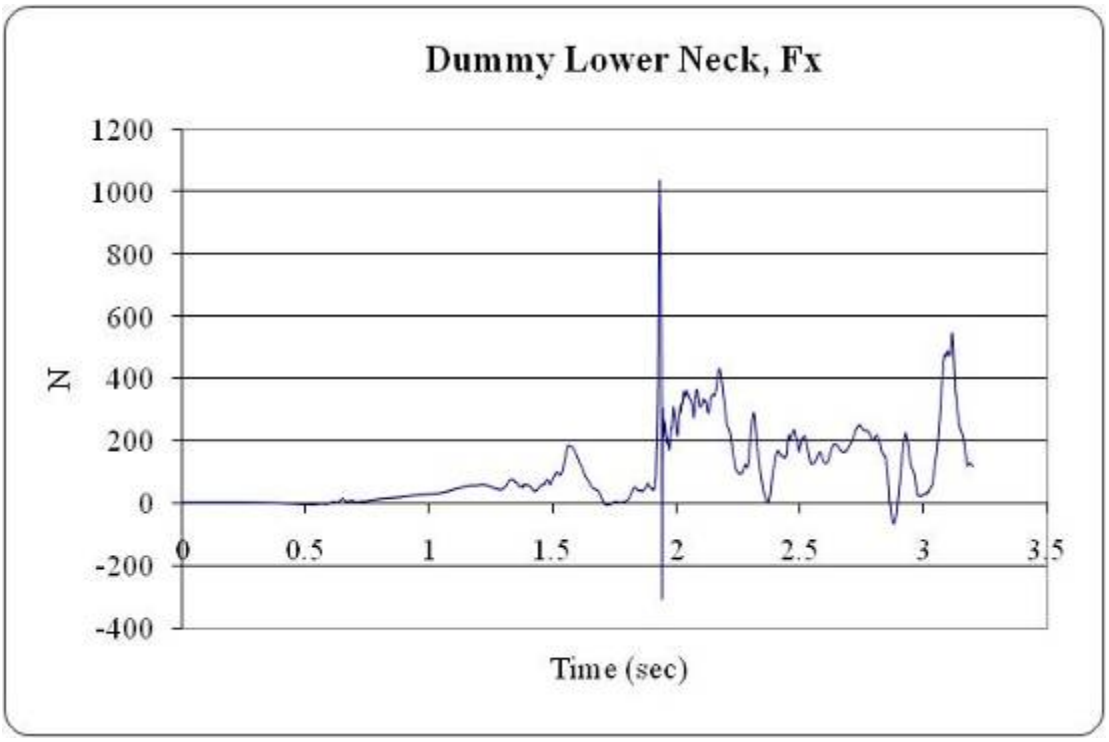
Data Sampling Rate: 10 kHz



Plot 24: String Potentiometer Passenger's Side A-Pillar Displacement v. Time

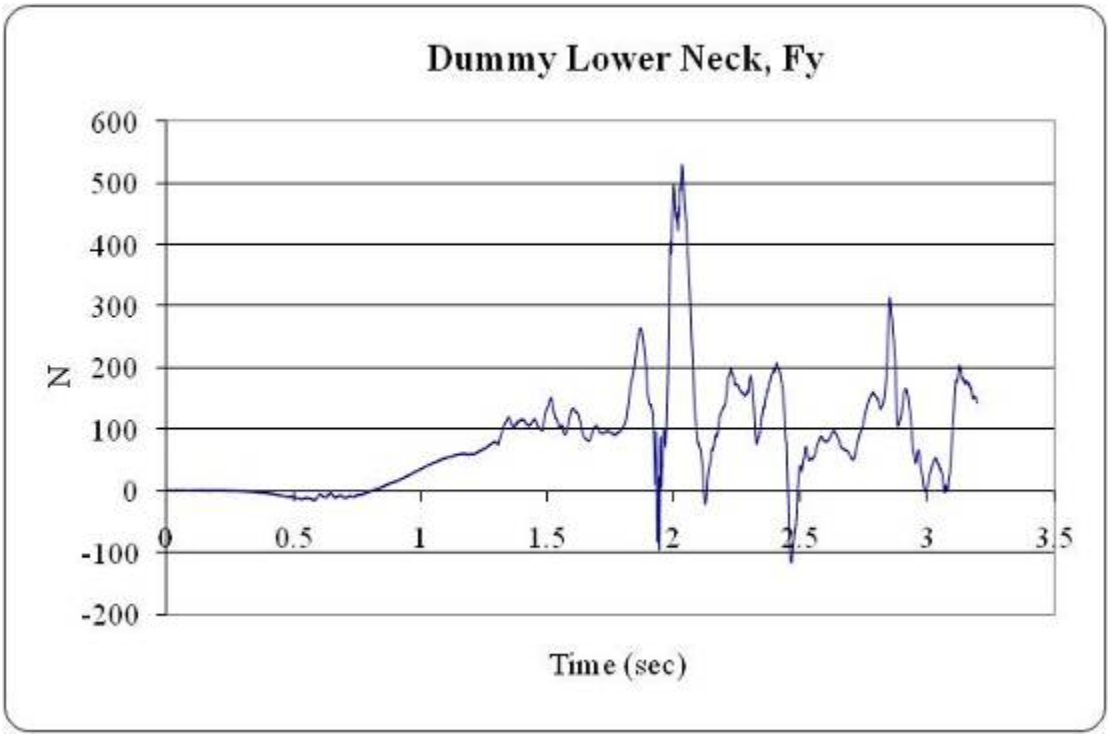
Data Sampling Rate: 10 kHz

Roll 2



Plot 25: Lower Neck Load, Fx, v. Time

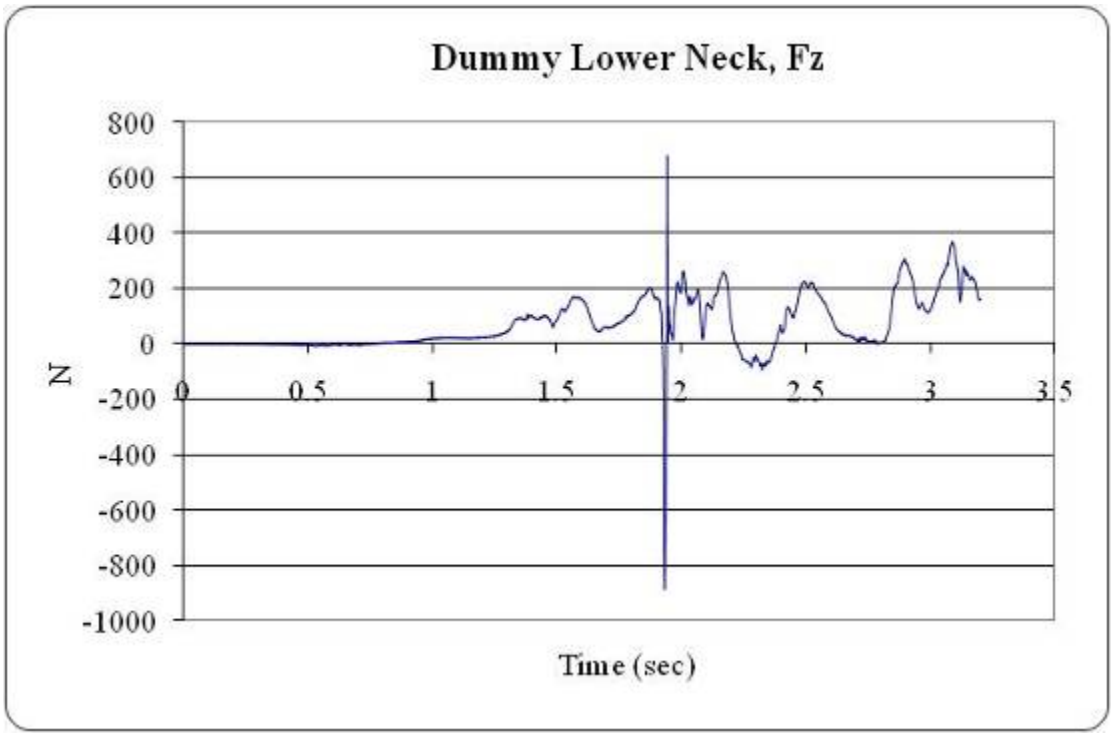
Data Sampling Rate: 10 kHz



Plot 26: Lower Neck Load, Fy, v. Time

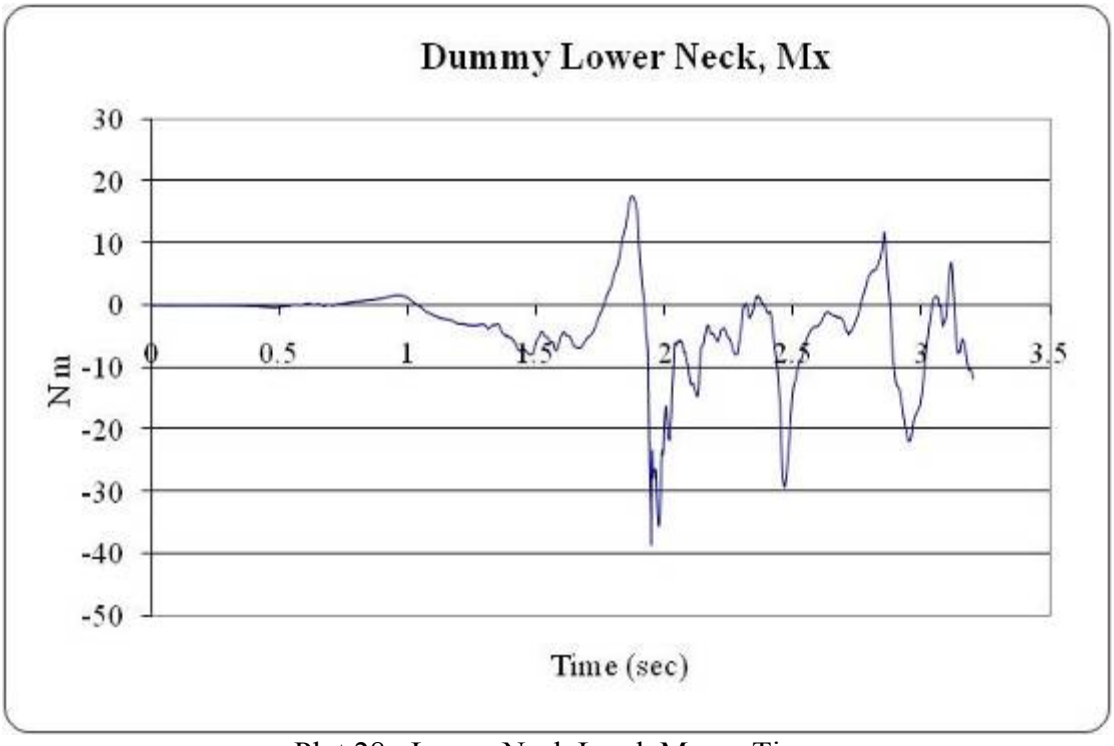
Data Sampling Rate: 10 kHz

Roll 2



Plot 27: Lower Neck Load, Fz, v. Time

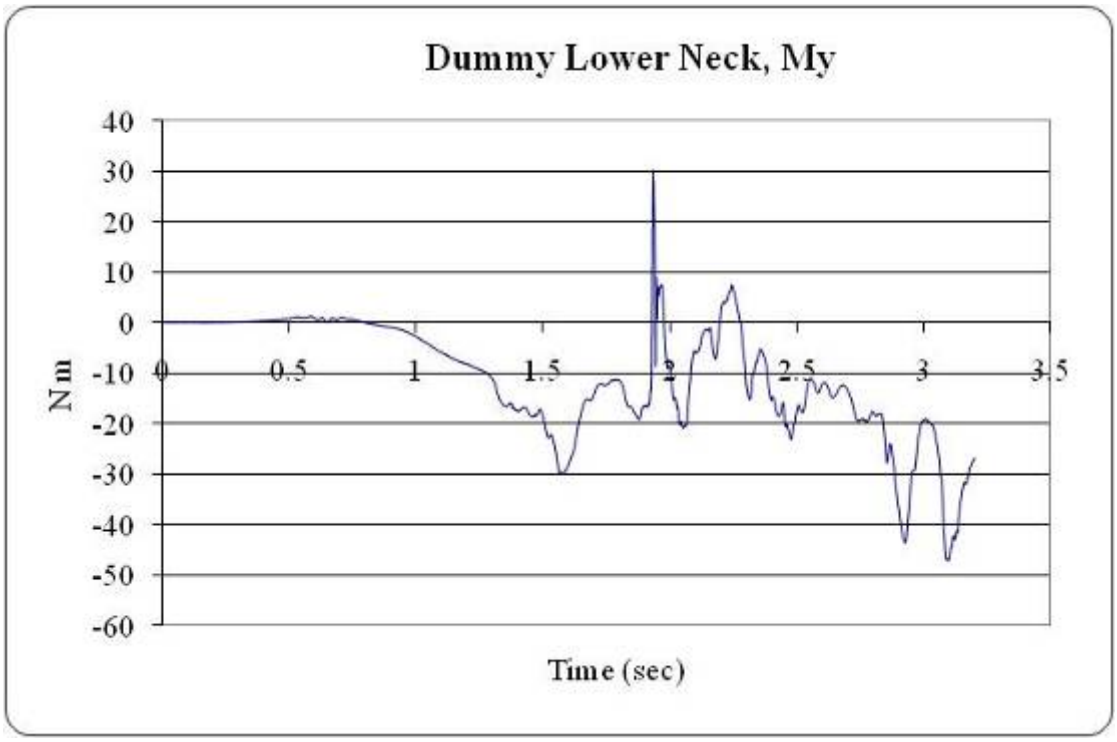
Data Sampling Rate: 10 kHz



Plot 28: Lower Neck Load, Mx, v. Time

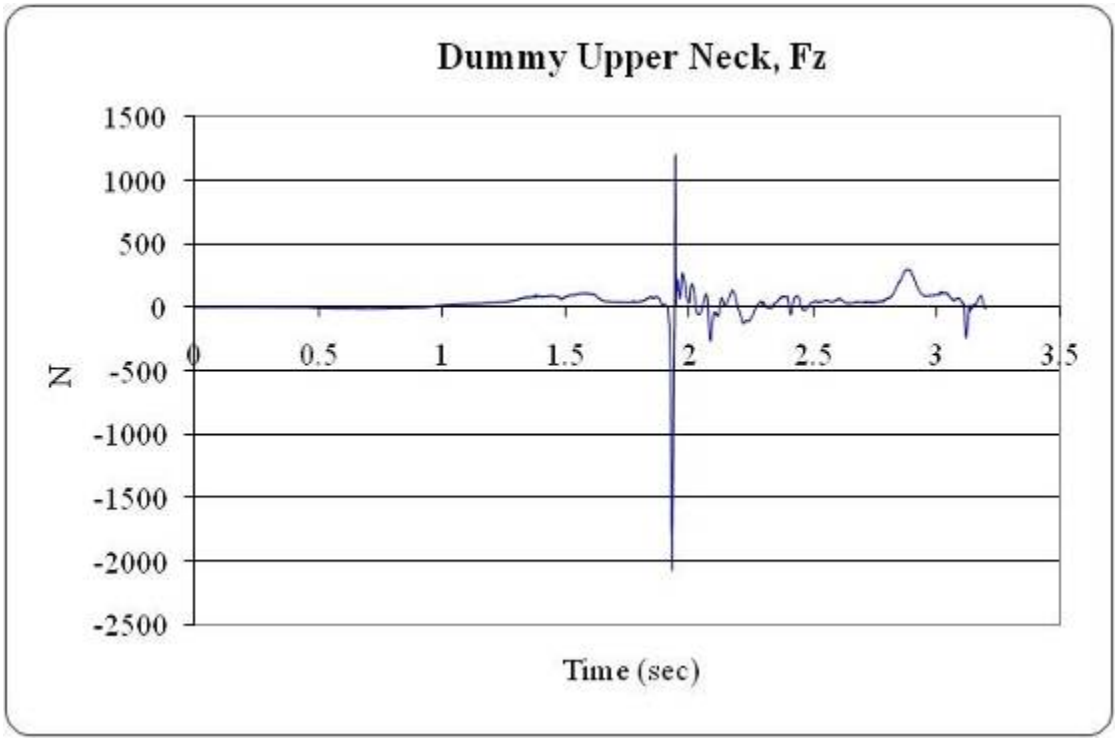
Data Sampling Rate: 10 kHz

Roll 2



Plot 29: Lower Neck Load, My, v. Time

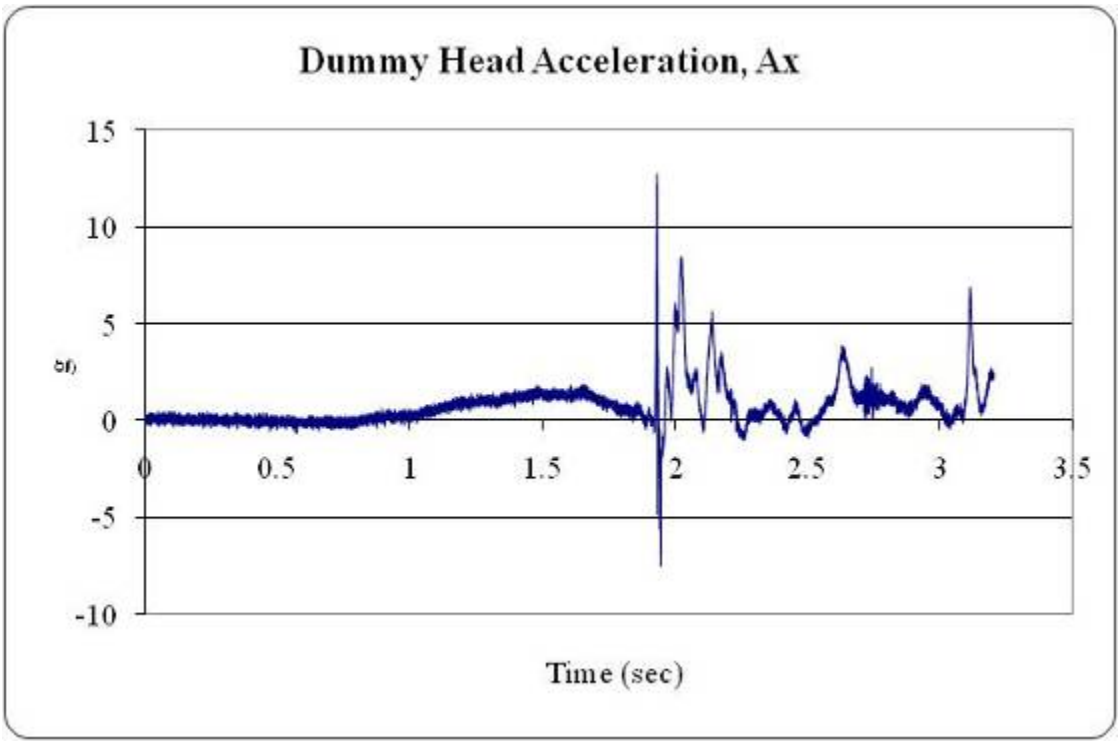
Data Sampling Rate: 10 kHz



Plot 30: Upper Neck Load, Fz, v. Time

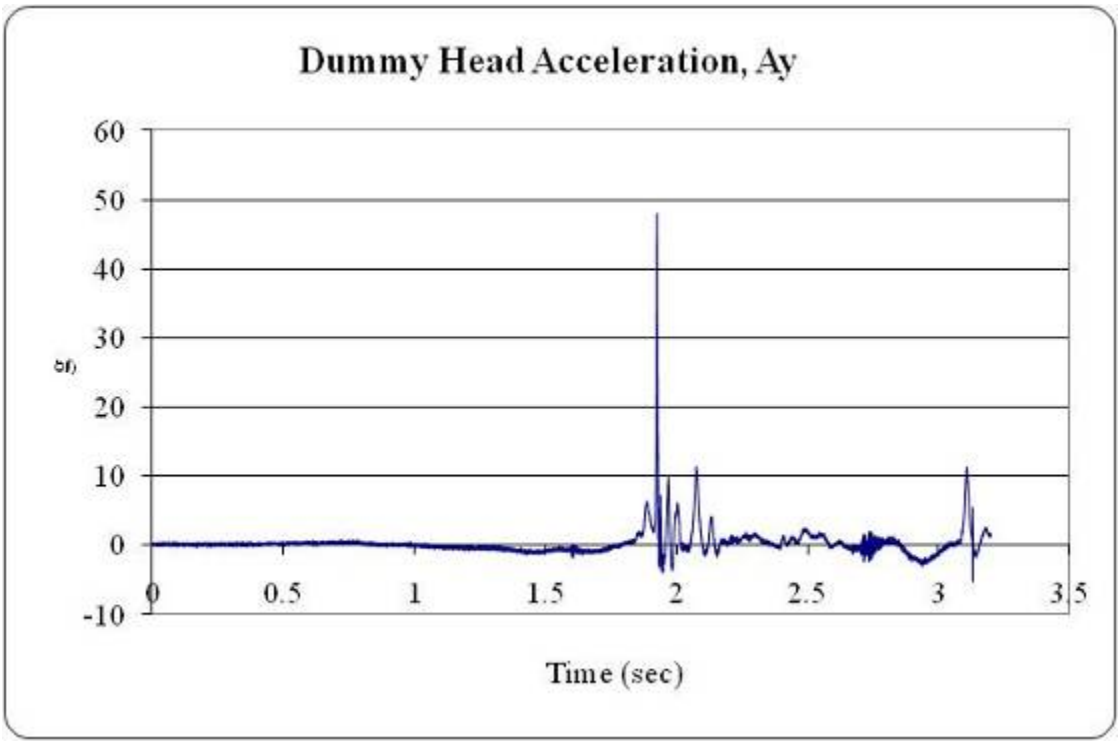
Data Sampling Rate: 10 kHz

Roll 2



Plot 31: Head Acceleration, Ax, vs. Time

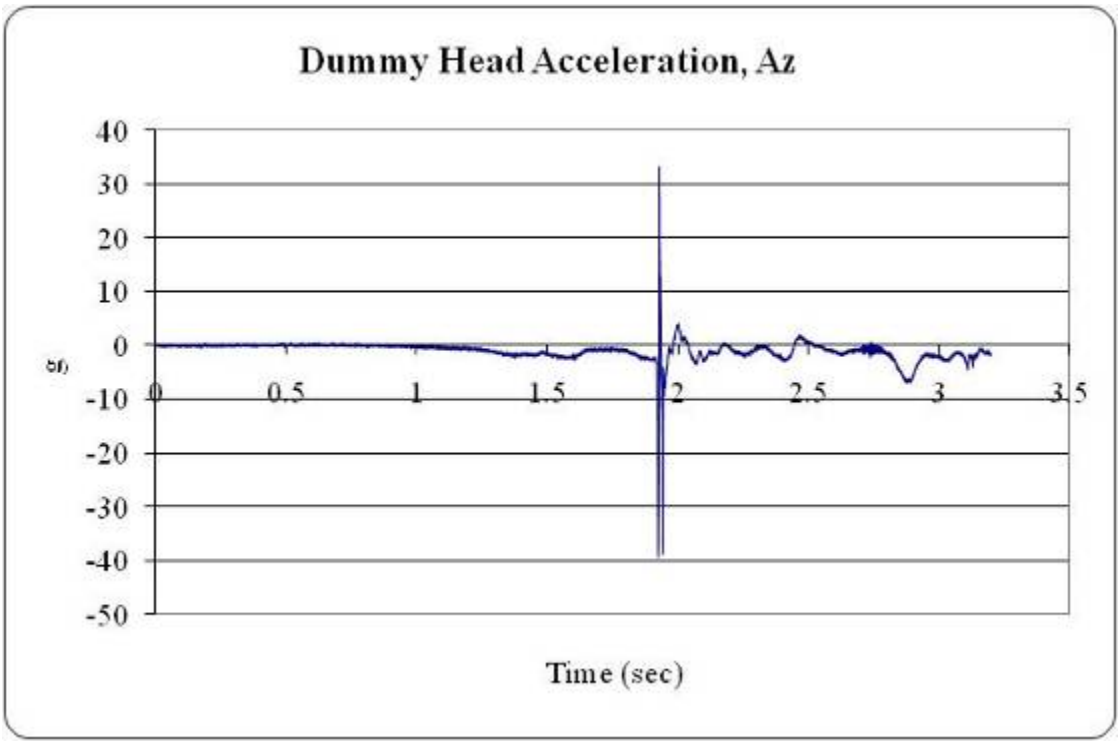
Data Sampling Rate: 10 kHz



Plot 32: Head Acceleration, Ay, vs. Time

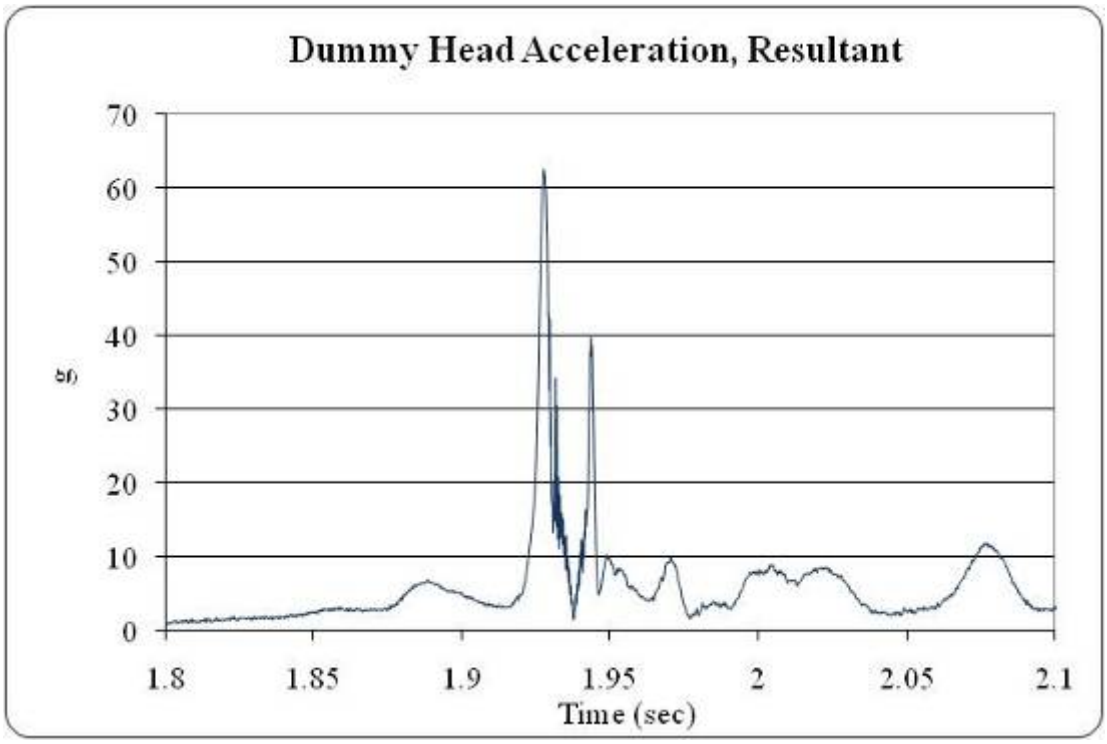
Data Sampling Rate: 10 kHz

Roll 2



Plot 33: Head Acceleration, Az, vs. Time

Data Sampling Rate: 10 kHz

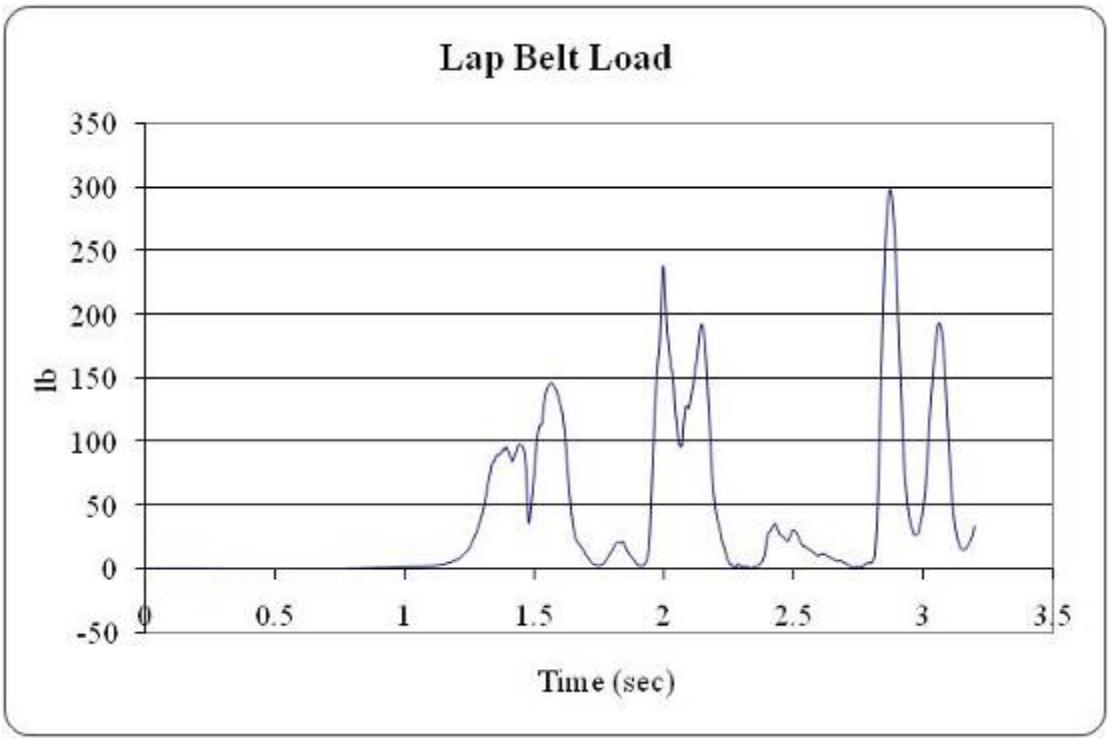


Plot 34: Resultant Head Acceleration vs. Time

HIC = 75

Data Sampling Rate: 10 kHz

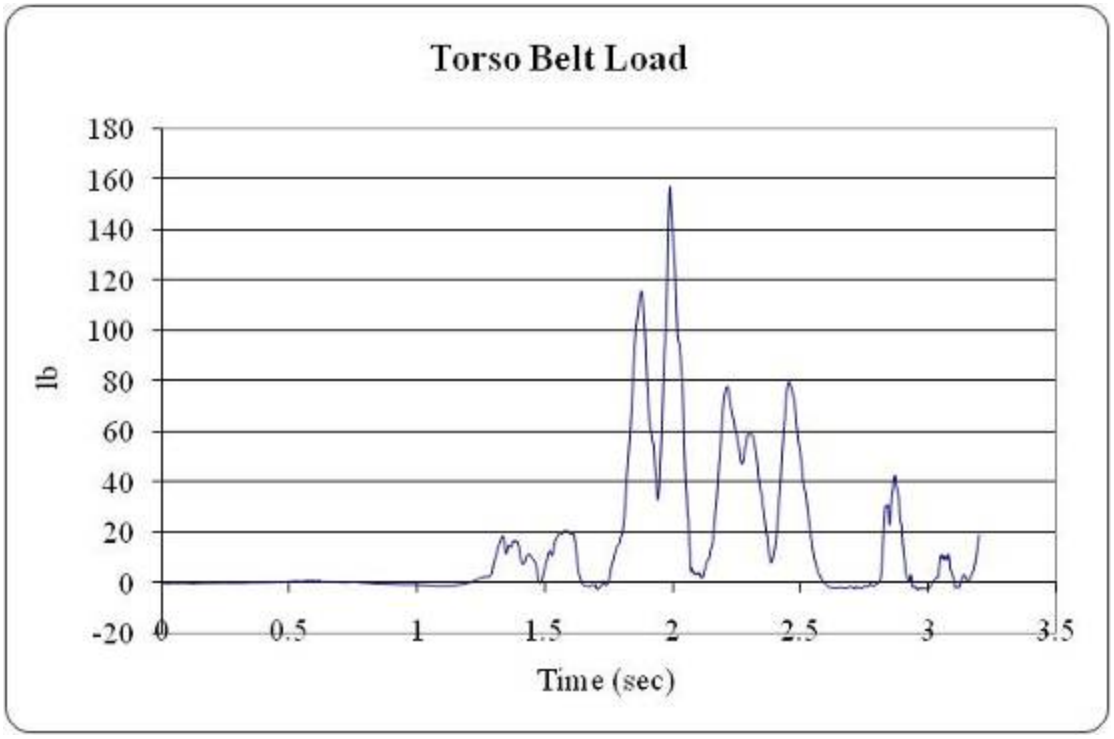
Roll 2



Plot 35: Lap Belt Load* vs. Time

*Measured on one side of the belt

Data Sampling Rate: 10 kHz

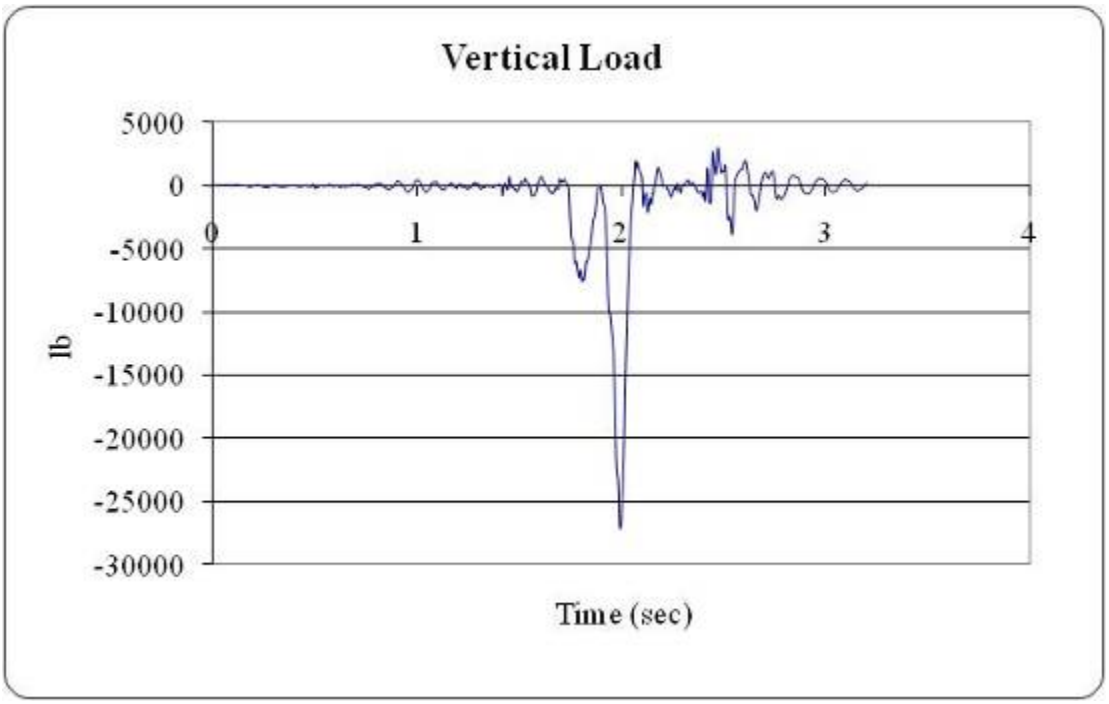


Plot 36: Torso Belt Load* vs. Time

*Measured on one side of the belt

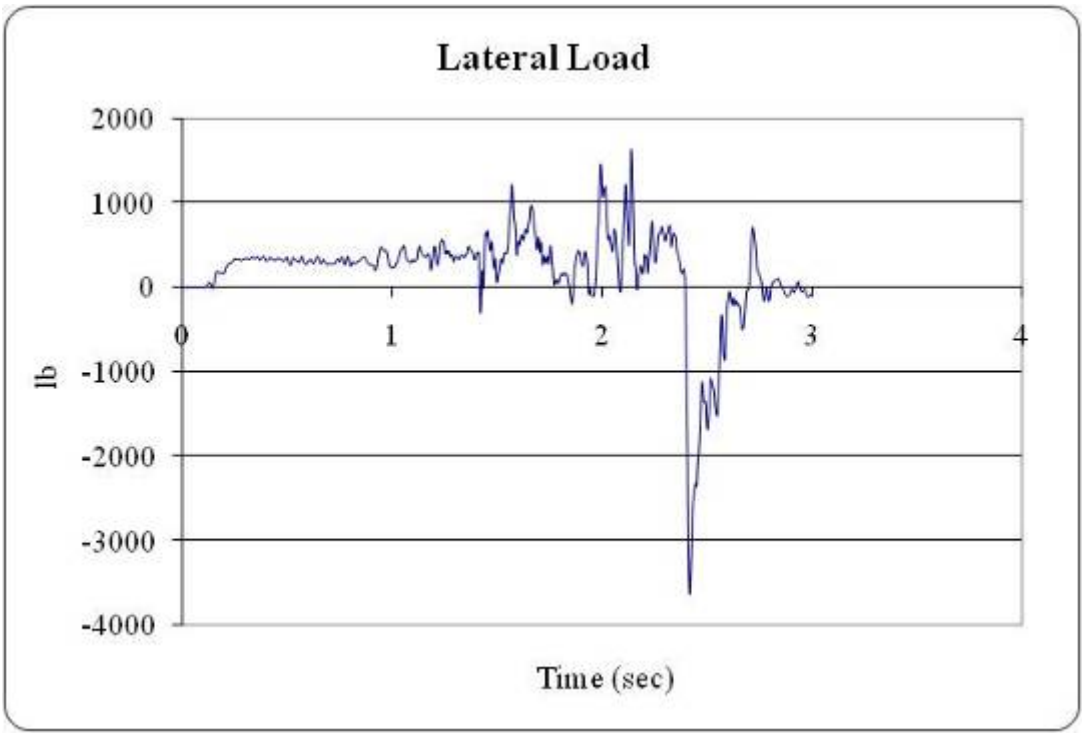
Data Sampling Rate: 10 kHz

Roll 2



Plot 37: Total Vertical Load v. Time

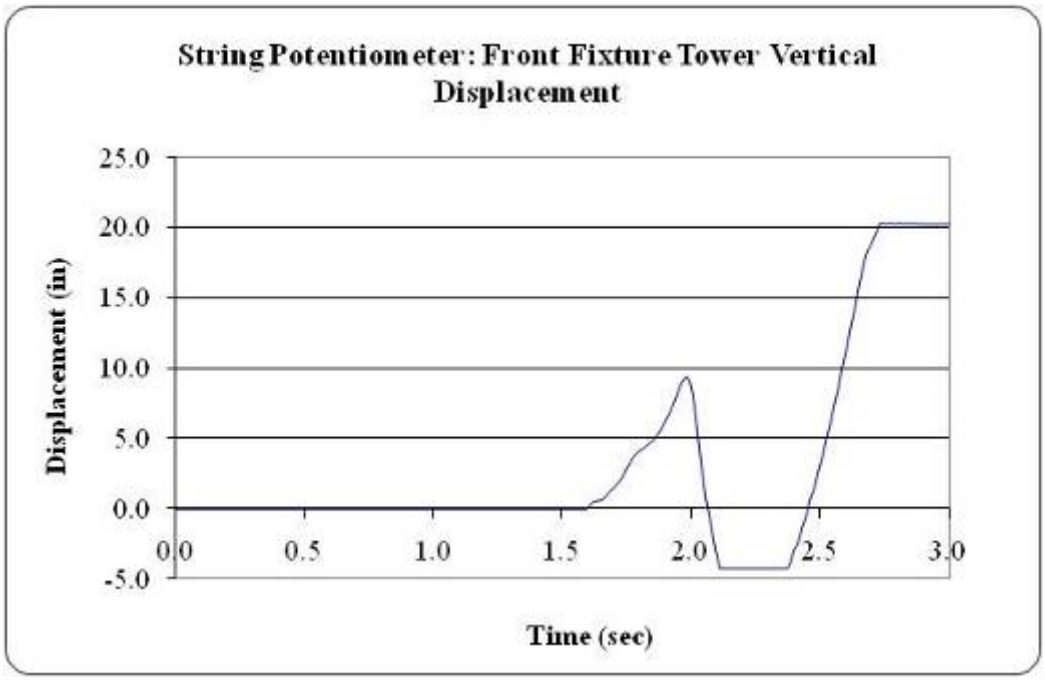
Data Sampling Rate: 10 kHz



Plot 38: Total Lateral Load v. Time

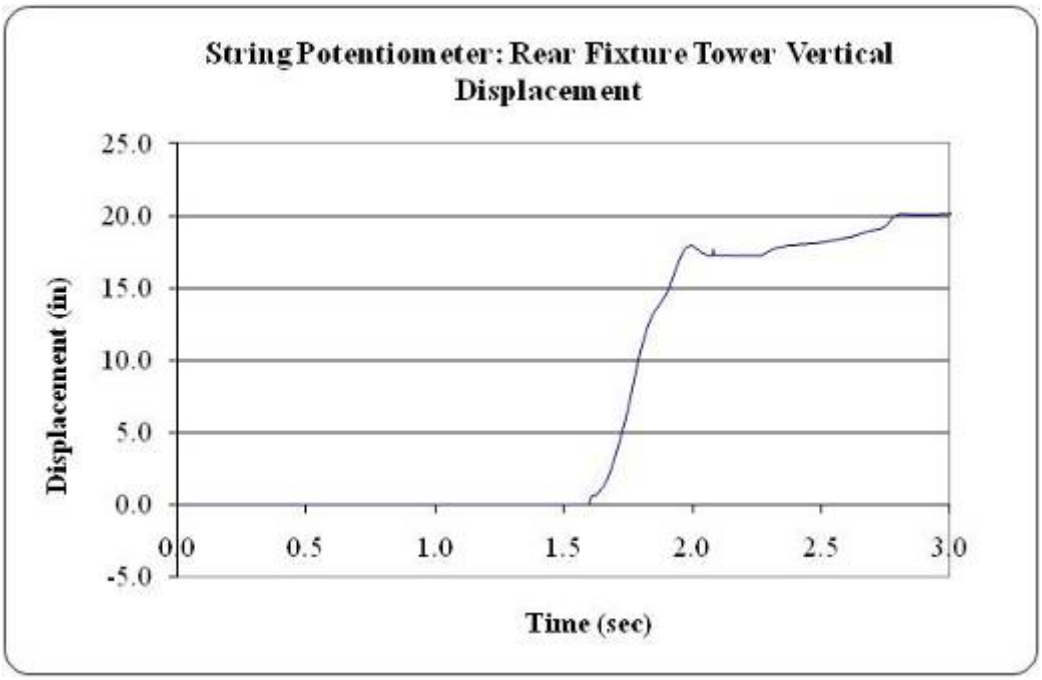
Data Sampling Rate: 10 kHz

Roll 2



Plot 39: String Potentiometer Front Fixture Support Tower Displacement vs. Time

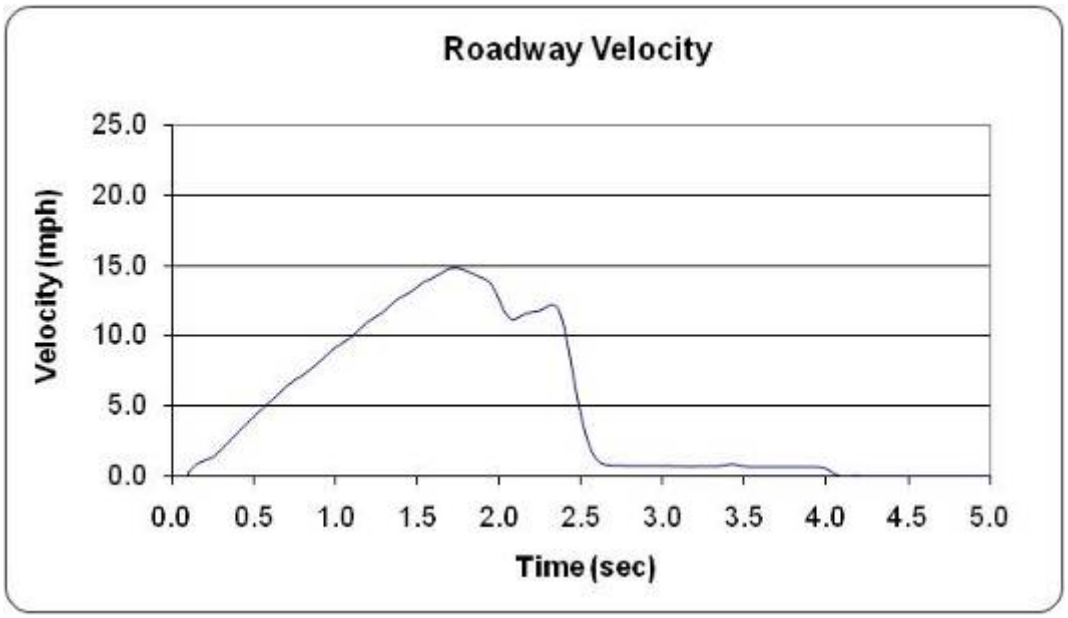
Data Sampling Rate: 1 kHz



Plot 40: String Potentiometer Rear Fixture Support Tower Displacement vs. Time

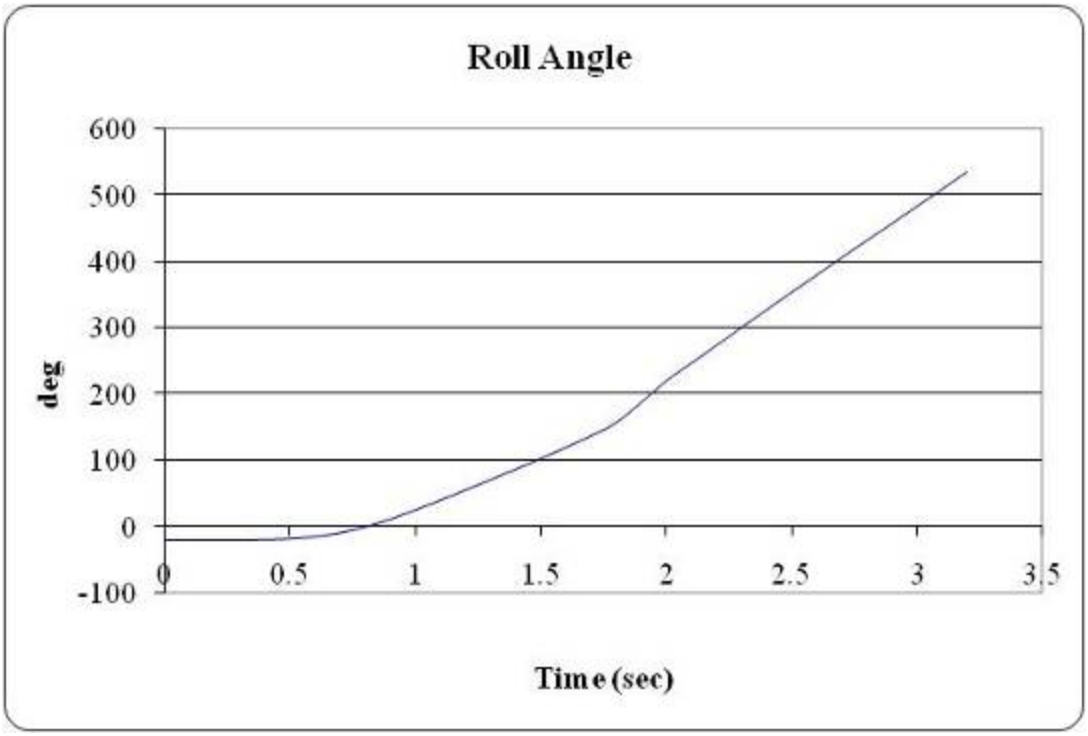
Data Sampling Rate: 1 kHz

Roll 2



Plot 41: Roll Encoder on Roadway Velocity vs. Time

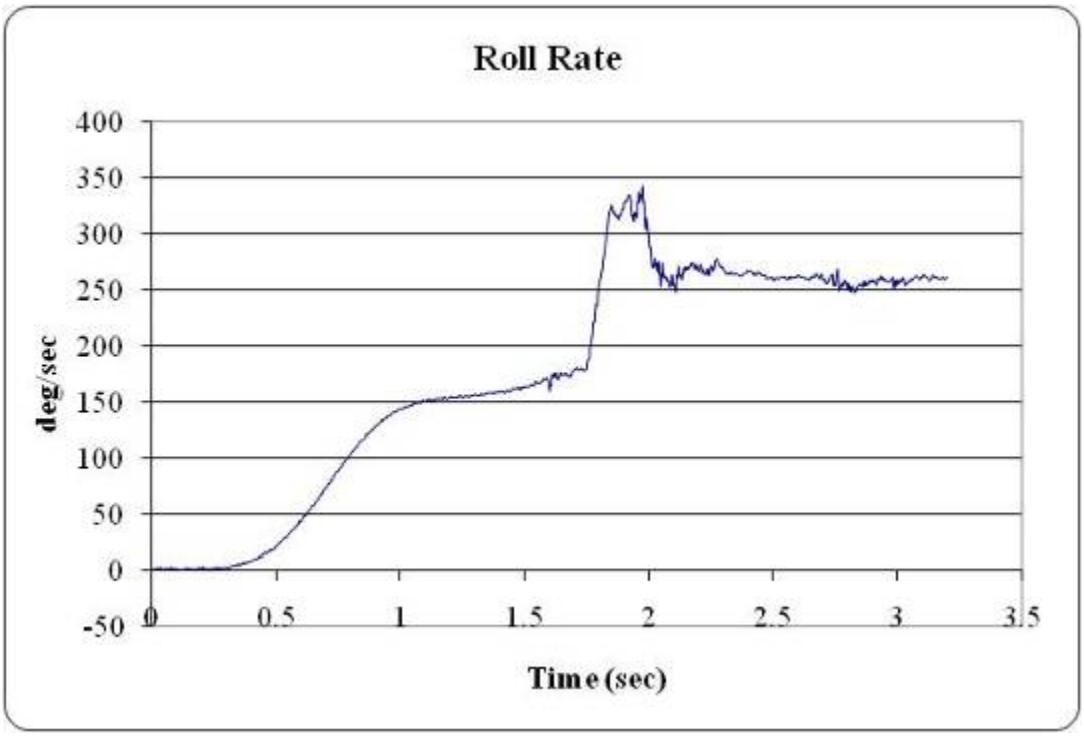
Data Sampling Rate: 1 kHz



Plot 42: Roll Angle vs. Time

Data Sampling Rate: 10 kHz

Roll 2

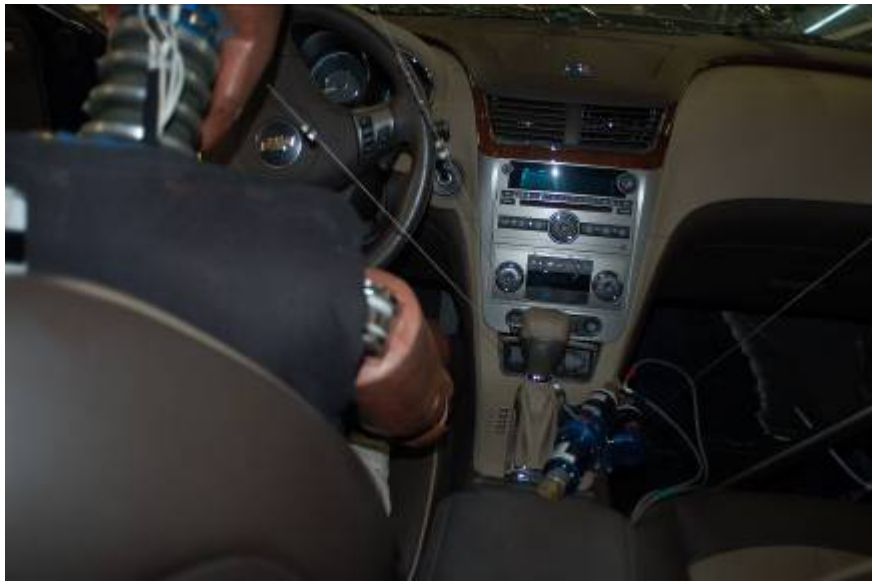


Plot 43: Roll Rate vs. Time

Data Sampling Rate: 10 kHz

5. All Test Photographs – Test Setup

Test Setup and Vehicle Instrumentation

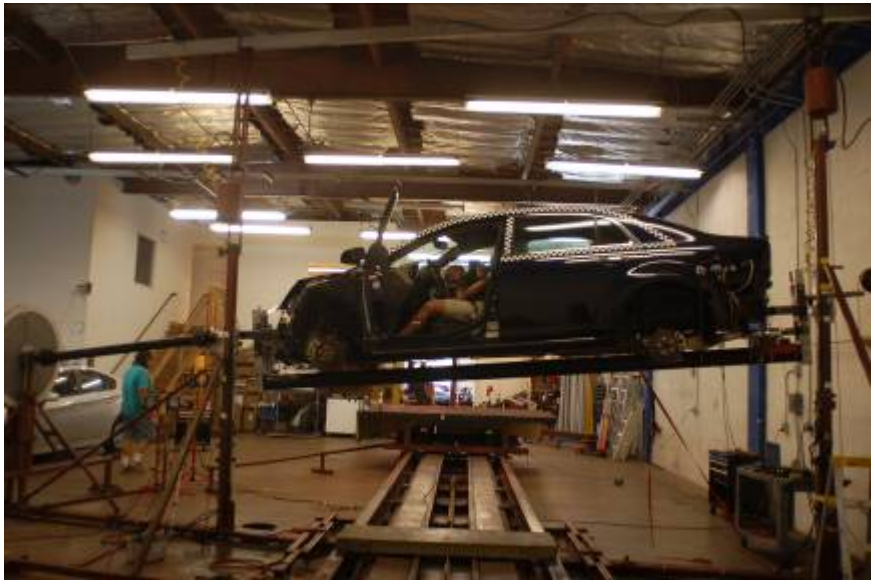


Vehicle Instrumentation

Roll 1 Photographs – 07/09/2010 – Dummy Inspection



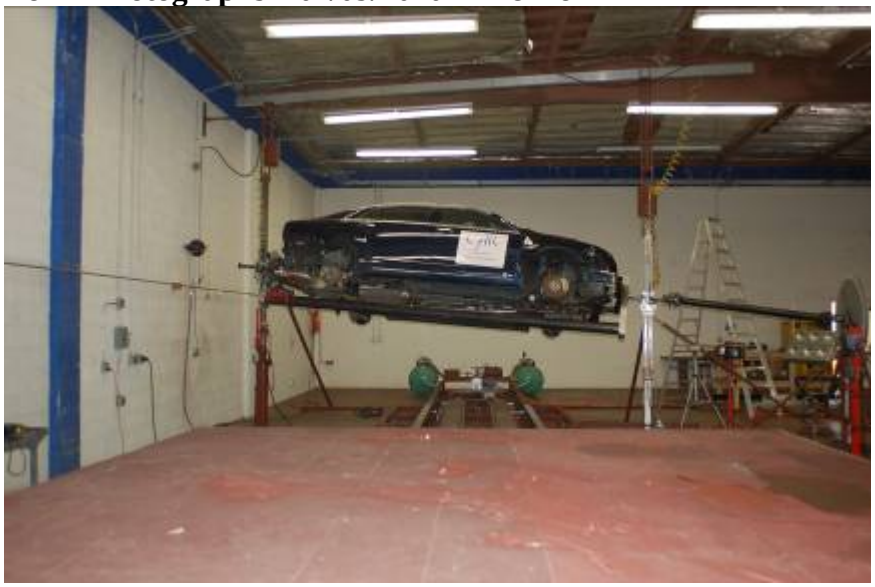

Roll 1 Photographs – 07/09/2010 – Dummy Inspection



Roll 1 Photographs – 07/09/2010 – Dummy Inspection




Roll 1 Photographs – 07/09/2010 – Pre-Roll

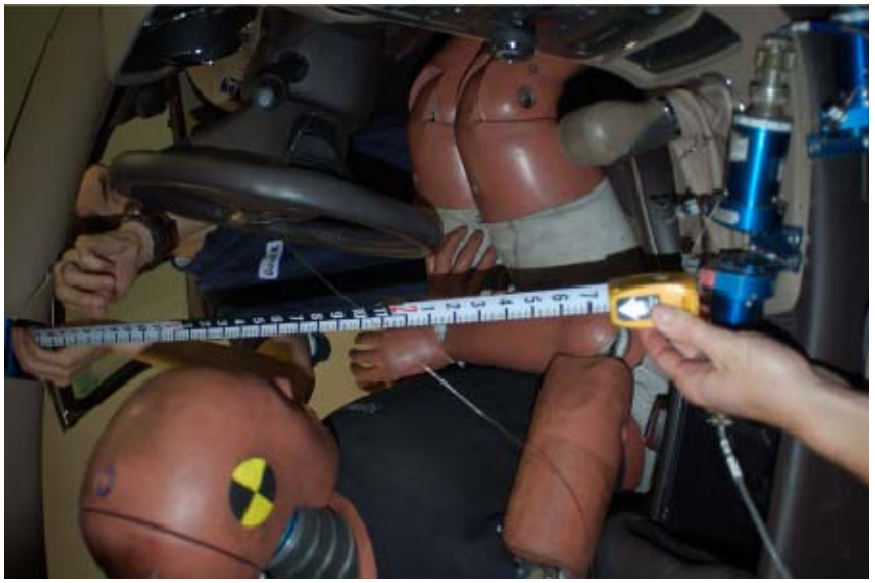


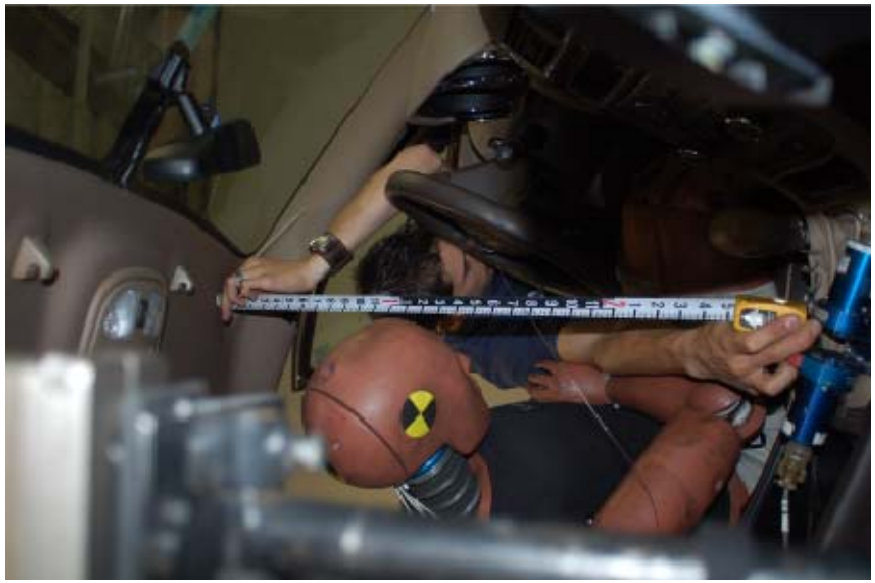

Roll 1 Photographs – 07/09/2010 – Pre-Roll




Roll 1 Photographs – 07/09/2010– Pre-Roll

Roll 1 Photographs – 07/09/2010 – Pre-Roll





Roll 1 Photographs – 07/09/2010 – Post-Roll




Roll 1 Photographs – 07/09/2010 – Post-Roll

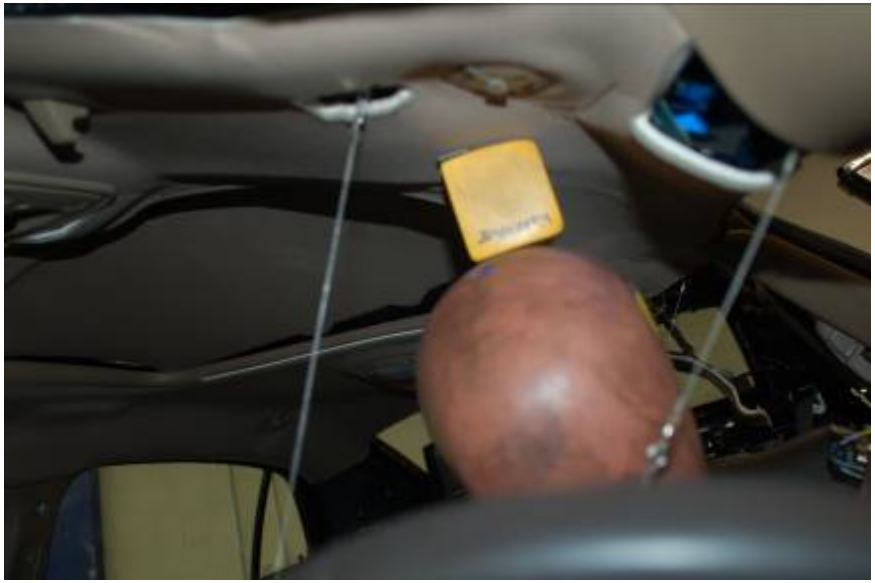
Roll 1 Photographs – 07/09/2010– Post-Roll




Roll 1 Photographs – 07/09/2010– Post-Roll

Roll 2 Photographs – 07/12/2010 – Dummy Inspection

Roll 2 Photographs – 07/12/2010 – Dummy Inspection



Roll 2 Photographs – 07/12/2010 – Pre-Roll




Roll 2 Photographs – 07/12/2010 – Pre-Roll




Roll 2 Photographs – 07/12/2010 – Pre-Roll

Roll 2 Photographs – 07/12/2010 – Pre-Roll

Roll 2 Photographs – 07/12/2010 – Post-Roll




Roll 2 Photographs – 07/12/2010 – Post-Roll




Roll 2 Photographs – 07/12/2010 – Post-Roll

Pre-Test

Pre-Test




Pre-Test

Post-Test

Post-Test