U.S. Department
of Transportation
**Federal Railroad
Administration**

Full-Scale Single Car Multilevel Car Test—Test No. 9 Procedures, Instrumentation, & Data

Office of Research and
Development
Washington, DC 20590

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March 2008
Draft Report

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13. ABSTRACT

This report addresses the efforts to document the behavior of an existing design multilevel passenger car as it impacts a stationary wall at approximately 36 mph. Transportation Technology Center, Inc.'s (TTCI) role was to instrument the vehicle per FRA direction, conduct the testing, report on the conduct of the test, and supply the instrumentation data to the FRA for analyses.

A full-scale impact test on October 2, 2007, utilizing an existing design multilevel passenger car was performed at the FRA's Transportation Technology Center in Pueblo, Colorado. The test was successful in meeting the requirements set forth in the approved Test Implementation Plan. The required data was collected along with high-speed video and post-test inspection results.

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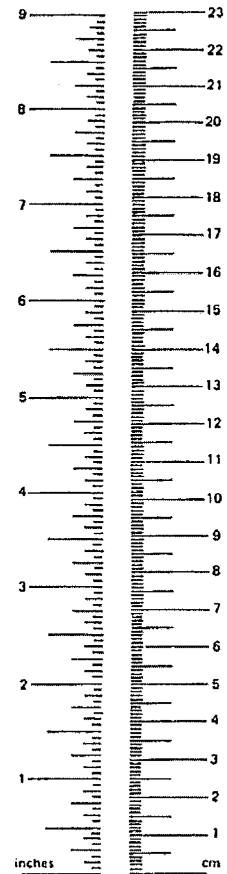
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

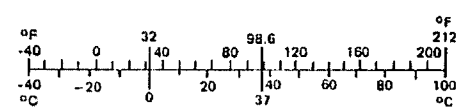
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.50	centimeters	cm
ft	feet	30.00	centimeters	cm
yd	yards	0.90	meters	m
mi	miles	1.60	kilometers	km
	AREA			
in^2	square inches	6.50	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.80	square meters	m^2
mi^2	square miles	2.60	square kilometers	km^2
	acres	0.40	hectares	ha
	MASS (weight)			
oz	ounces	28.00	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.90	tonnes	t
	VOLUME			
tsp	teaspoons	5.00	milliliters	ml
Tbsp	tablespoons	15.00	milliliters	ml
fl oz	fluid ounces	30.00	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.80	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 cm (exactly)



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.40	inches	in
m	meters	3.30	feet	ft
m	meters	1.10	yards	yd
km	kilometers	0.60	miles	mi
	AREA			
cm^2	square centim.	0.16	square inches	in^2
m^2	square meters	1.20	square yards	yd^2
km^2	square kilom.	0.40	square miles	mi^2
ha	hectares (10,000 m^2)	2.50	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.10	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36.00	cubic feet	ft^3
m^3	cubic meters	1.30	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

The Office of Research and Development of the Federal Railroad Administration (FRA) has been conducting research on rail equipment crashworthiness with the approach of reviewing relevant accidents, identifying options for design modifications to improve occupant survivability, and applying analytical tools and testing techniques to assess the effectiveness of such options. As part of this research, computer models have been developed and used to determine the response of passenger rail equipment in different collision scenarios. To assess the validation of these computer models, results of these analyses have been compared with accident data, and components test results. The information learned in the research will be used to develop safety rulemaking requirements for passenger equipment end frame designs.

This report addresses the efforts to document the behavior of an existing design multilevel passenger car as it impacts a stationary wall at approximately 36 mph. Transportation Technology Center, Inc.'s (TTCI) role was to instrument the vehicle per FRA direction, conduct the testing, report on the conduct of the test, and supply the instrumentation data to the FRA for analyses.

A full-scale impact test on October 2, 2007, utilizing an existing design multilevel passenger car was performed at the FRA's Transportation Technology Center (TTC) in Pueblo, Colorado.

The test was successful in meeting the requirements set forth in the approved Test Implementation Plan. The required data was collected along with high-speed video and post-test inspection results.

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1.0 Introduction

The Office of Research and Development of the FRA has been conducting research on rail equipment crashworthiness with the approach of reviewing relevant accidents, identifying options for design modifications to improve occupant survivability and applying analytical tools and testing techniques to assess the effectiveness of such options. As part of this research, computer models have been developed and used to determine the response of passenger rail equipment in different collision scenarios. To assess the validation of these computer models, results of these analyses have been compared with accident data, and components test results. The information learned in the research will be used to develop safety rulemaking requirements for passenger equipment end frame designs.

This report addresses the efforts to document the behavior of an existing design multilevel passenger car as it impacts a stationary wall at approximately 36 mph. TTCI's role was to instrument the vehicle per FRA direction, conduct the testing, report on the conduct of the test, and supply the instrumentation data to the FRA for analyses.

A full-scale impact test on October 2, 2007, utilizing an existing design multilevel passenger car was performed at the FRA's TTC, Pueblo, Colorado.

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2.0 Test Car

The test was conducted using a Generation 1 Bombardier multilevel passenger car (SCAX 113) supplied by the FRA for this program (Figure 1). All ancillary and removable equipment was stripped from the car. The car was instrumented according to the Test Implementation Plan (TIP) approved by the FRA on September 18, 2007 (Appendix A). Grid lines and targets were added to the car end to aid in the post-test analysis.

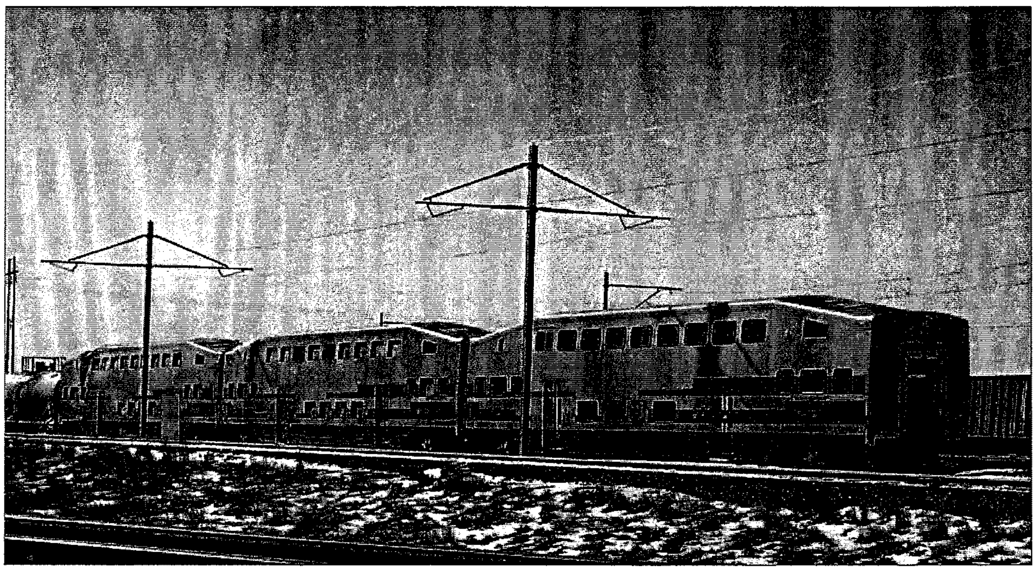

Figure 1. Test Vehicle Arrives at TTC

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3.0 Test Methodology

The impact test was performed at TTC by pushing the test car with a locomotive to a predetermined speed, releasing the car at a predetermined location, and letting the test car roll along the track into the impact wall. The distance from the impact point at which the test car was released and the speed of the locomotive at the release point was determined by a series of speed calibration runs carried out before the test on a track parallel to the impact track. During these speed calibration runs, a radar speed measuring system was used to precisely measure the speed of the test vehicle. For the impact test, dual redundant reflector-sensing speed traps were used to precisely measure the speed of the test car just before impact and the radar system was used for redundancy.

The barrier itself, constructed of reinforced concrete and steel has an estimated weight of 1,350 tons and is capable of withstanding an impact force of 3,000,000 pounds (13.4 MN). The front face of the barrier is 2-foot-thick reinforced concrete faced with a 3-inch-thick steel plate.

Onboard instrumentation was used to record accelerations, strains, and displacements at various points on the car during and after the impact per the approved TIP. High-speed video cameras were used to record the impact from several different vantage points.

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4.0 Measurements

4.1 Weight of Test Car

The test car was weighed prior to the impact test using the TTC computerized scale. The trailing end, or A-end, weight of the car was 47,975 pounds. The leading end, or B-end, weight of the car was 47,425 pounds. This resulted in a total vehicle weight of 95,400 pounds. The accuracy of the weighbridge is +/- 50 pounds; therefore, the accuracy of the vehicle weight is +/- 100 pounds.

4.2 Weather Conditions

The weather conditions just prior to the test:

- Temperature: 73°F
- Wind Speed: 10.4 mph due west with 24 mph gusts

4.3 Speed

Dual, redundant, optical speed traps were used to determine the impact speed of the test vehicle. A radar gun was also used to verify the measurements and offer a second level of redundancy. The speed traps utilized two optical sensors mounted to the A-end (trailing) truck on the test vehicle and two reflector arrays mounted to the track structure. The measured speed trap data were as follows:

- Right Speed Trap 53.4 ft/sec (36.4 mph)
- Left Speed Trap 53.7 ft/sec (36.6 mph)

The radar gun verified the magnitude of these measurements.

4.4 Accelerations

Five three-axis accelerometers and 10 two-axis (longitudinal and vertical) accelerometers were used to measure the gross acceleration levels experienced by the carbody during the impact test. In addition, the accelerations of each truck were measured with one two-axis (longitudinal and vertical) accelerometer and the longitudinal acceleration of the striking coupler was measured using two accelerometers for redundancy.

The accelerometer type (range) for each measurement varied from the TIP for some measurements due to the availability of accelerometers within the FRA's inventory at TTC. All changes to accelerometer type were within the acceptable range to capture the expected performance.

Table 1 lists the final location, the car end (B-end leading), the car side (facing in direction of travel), the direction being measured, and the accelerometer range. Figure 2 illustrates the accelerometer locations.

Appendix B contains the results of the acceleration measurements.

Table 1. Final Location, Car End, Car Side, Direction, Accelerometer Range

End	Side	Location	X-Longitudinal	Y-Lateral	Z-Vertical	Range
B	L	Front of Bolster	AL1X	-	AL1Z	X-400G Z-200G
B	-	Front of Bolster	AC1X	AC1Y	AC1Z	X-400G Y-200G Z-400G
B	R	Front of Bolster	AR1X	-	AR1Z	X-400G Z-200G
B	L	Rear of Bolster	AL2X	-	AL2Z	X-400G Z-200G
B	-	Rear of Bolster	AC2X	AC2Y	AC2Z	X-400G Y-200G Z-400G
B	R	Rear of Bolster	AR2X	-	AR2Z	X-400G Z-200G
B	L	Gooseneck	AL3X	-	AL3Z	X-400G Z-200G
B	-	Gooseneck	AC3X	AC3Y	AC3Z	X-400G Y-100G Z-400G
B	R	Gooseneck	AR3X	-	AR3Z	X-400G Z-200G
-	L	Approximate C.G.	AL4X	-	AL4Z	X-200G Z-100G
-	-	Approximate C.G.	AC4X	AC4Y	AC4Z	X-400G Y-100G Z-200G
-	R	Approximate C.G.	AR4X	-	AR4Z	X-200G Z-100G
A	L	Rear of Bolster	AL5X	-	AL5Z	X-200G Z-100G
A	-	Rear of Bolster	AC5X	AC5Y	AC5Z	X-400G Y-100G Z-200G
A	R	Rear of Bolster	AR5X	-	AR5Z	X-400G Z-200G
B	-	B-end Truck	ABTX	-	ABTZ	X-200G Z-200G
A	-	A-end Truck	AATX	-	AATZ	X-200G Z-200G

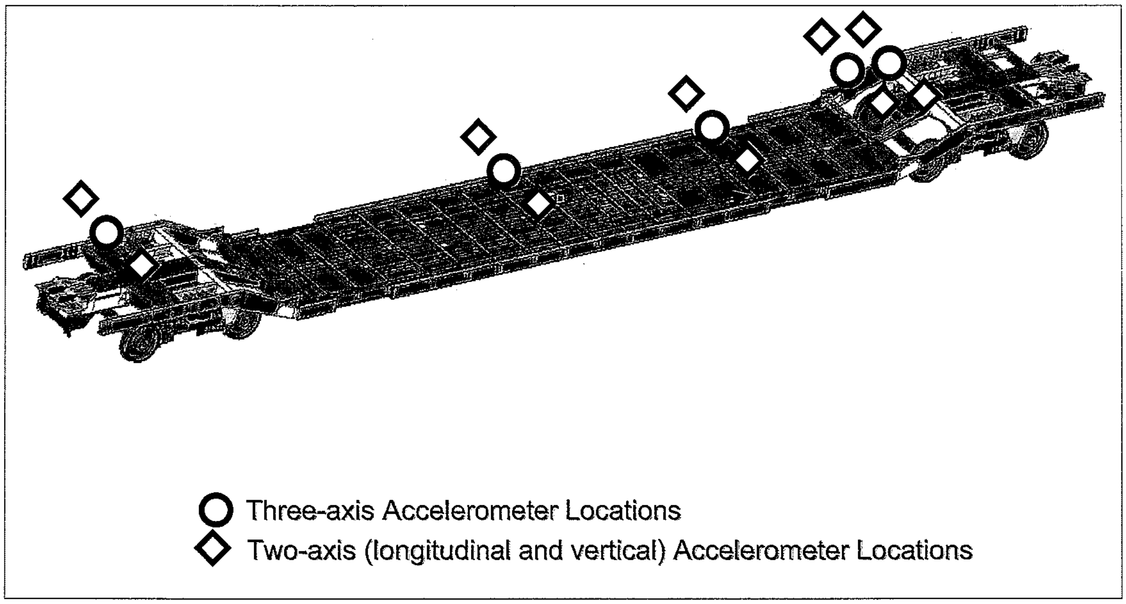


Figure 2. Accelerometer Locations

4.5 Strains

Thirty-six standard strain gages were used to measure the strains in the leading (impact) end of the vehicle. Twelve gages were installed on each side of the vehicle, six on the cant rail and six on the side sill at the locations, as Figure 3 illustrates. Additionally, 12 strain gages were installed on the center sill of the vehicle, as Figure 4 illustrates. Appendix C contains the data.

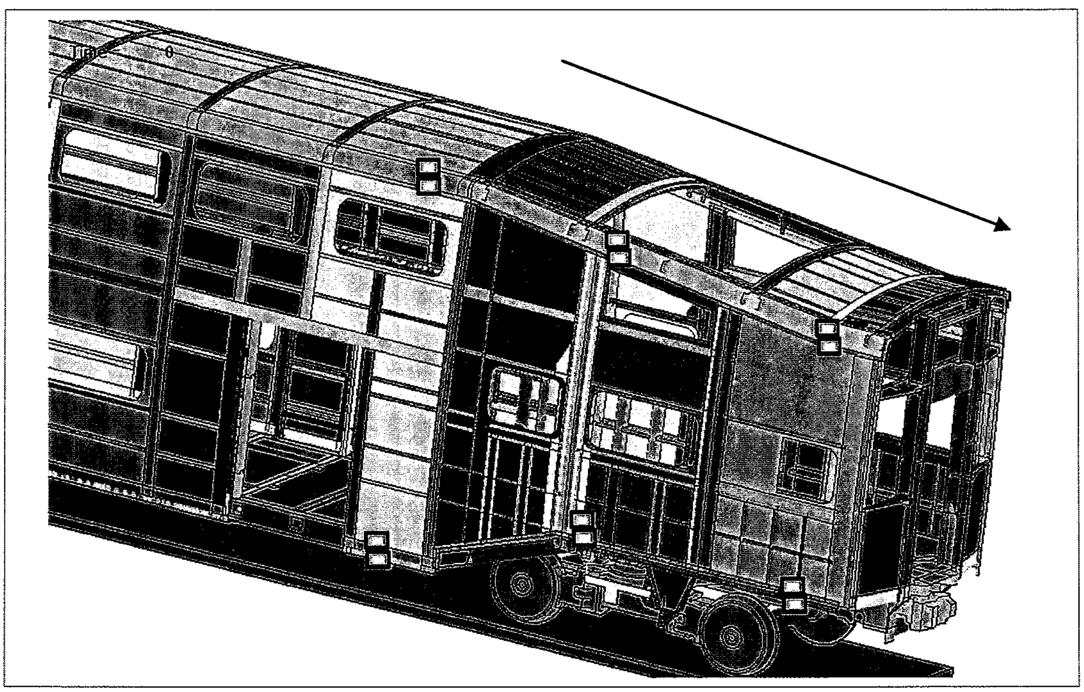


Figure 3. Strain Gage Locations on the Exterior of Vehicle

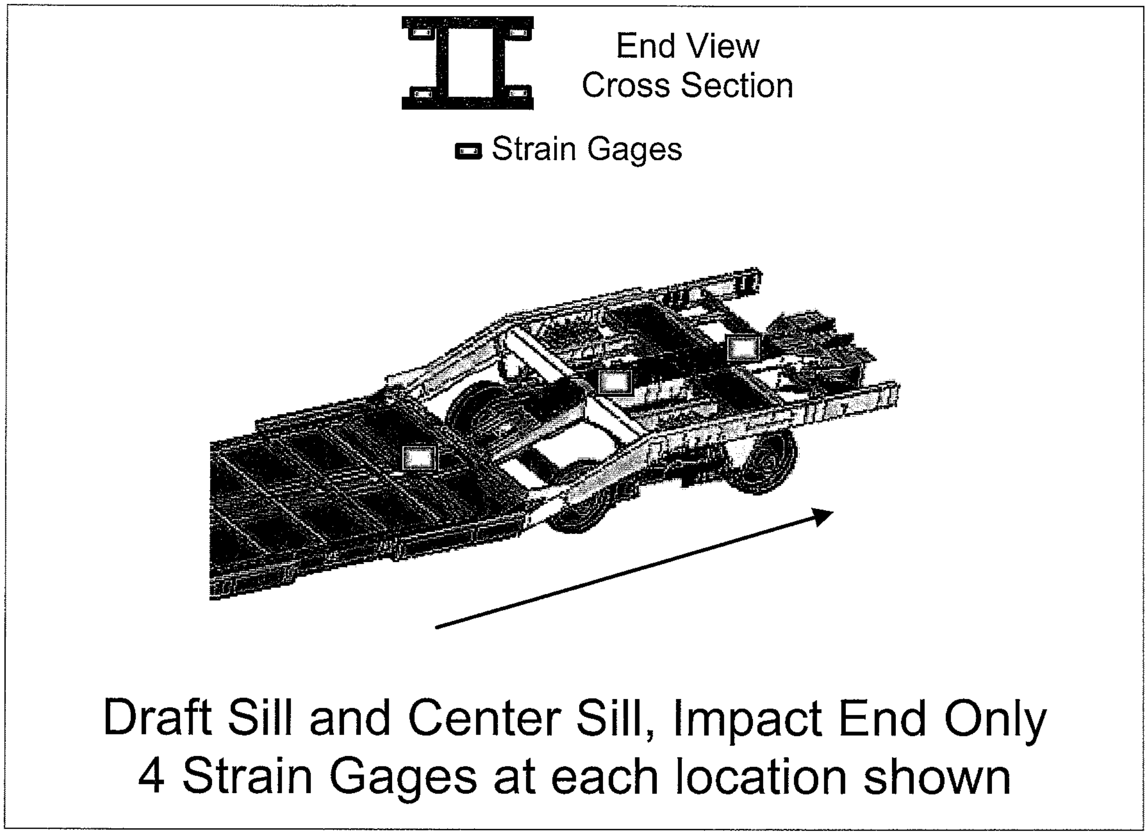


Figure 4. Strain Gage Locations on Center Sill of Vehicle

Table 2 lists the channel name and location for each of the gages installed.

Table 2. Gage Channel Name and Location

Channel Names	Location
SLST1T SLST1B	T1 – left cant rail, leading position
SLST2T SLST2B	T2 – left cant rail, middle position
SLST3T SLST3B	T3 – left cant rail, trailing position
SRST1T SRST1B	T1 – right cant rail, leading position
SRST2T SRST2B	T2 – right cant rail, middle position
SRST3T SRST3B	T3 – right cant rail, trailing position
SLSB1T SLSB1B	B1 – left side sill, leading position
SLSB2T SLSB2B	B2 – left side sill, middle position
SLSB3T SLSB3B	B3 – left side sill, trailing position
SRSB1T SRSB1B	B1 – right side sill, leading position
SRSB2T SRSB2B	B2 – right side sill, middle position
SRSB3T SRSB3B	B3 – right side sill, trailing position
SCSBRTL SCSBRTR	Center sill, rear of bolster, Top left and right location
SCSBRBL SCSBRBR	Center sill, rear of bolster, bottom left and right location
SCSBFTL SCSBFTR	Center sill, front of bolster, top left and right location
SCSBFBL SCSBFBR	Center sill, front of bolster, bottom left and right location
SCSGNTL SCSGNTR	Center sill, @ gooseneck, top left and right location
SCSGNBL SCSGNBR	Center sill @ gooseneck, bottom left and right location

4.6 Displacements

Four displacement transducers measured displacements during the impact across the gooseneck section on the impact end of the car, one displacement transducer were installed across each spring group, and two displacement transducers were installed on the impact coupler. Figure 5 depicts the approximate locations of these transducers. Table 3 gives the string potentiometer ranges and channel names. Appendix D contains the results from the displacement measurements.

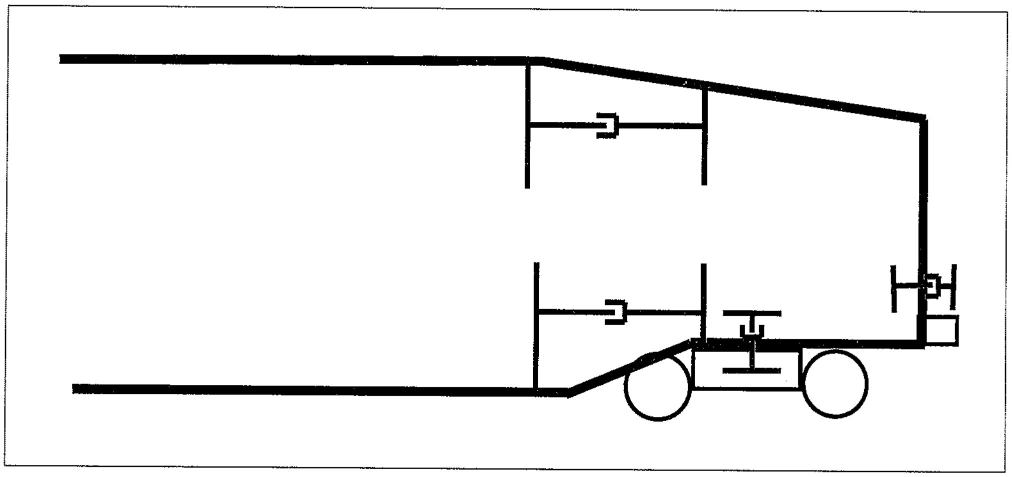


Figure 5. Displacement Transducer Locations

Table 3. String Potentiometer Ranges and Channel Names

End	Side	Location	Orientation	Channel Name	Range
B	L	Top @ Gooseneck	X - longitudinal	DBGNTL	50 in.
B	L	Bottom @ Gooseneck	X - longitudinal	DBGNBL	50 in.
B	R	Top @ Gooseneck	X - longitudinal	DBGNTR	50 in.
B	R	Bottom @ Gooseneck	X - longitudinal	DBGNBR	50 in.
B	L	Leading Truck	Z - vertical	DBTL	20 in.
B	R	Leading Truck	Z – vertical	DBTR	20 in.
A	L	Trailing Truck	Z – vertical	DATL	20 in.
A	R	Trailing Truck	Z – vertical	DATR	20 in.
B	-	Impact Coupler	X - longitudinal	DBCPLX	20 in.
B	-	Impact Coupler	Y – lateral	DBCPLY	20 in.

4.7 High-Speed and Real-Time Photography

Nine high-speed digital cameras and two video cameras were used to document the impact test. Figure 6 shows the approximate positions of these cameras. The videos were delivered to the FRA following the test.

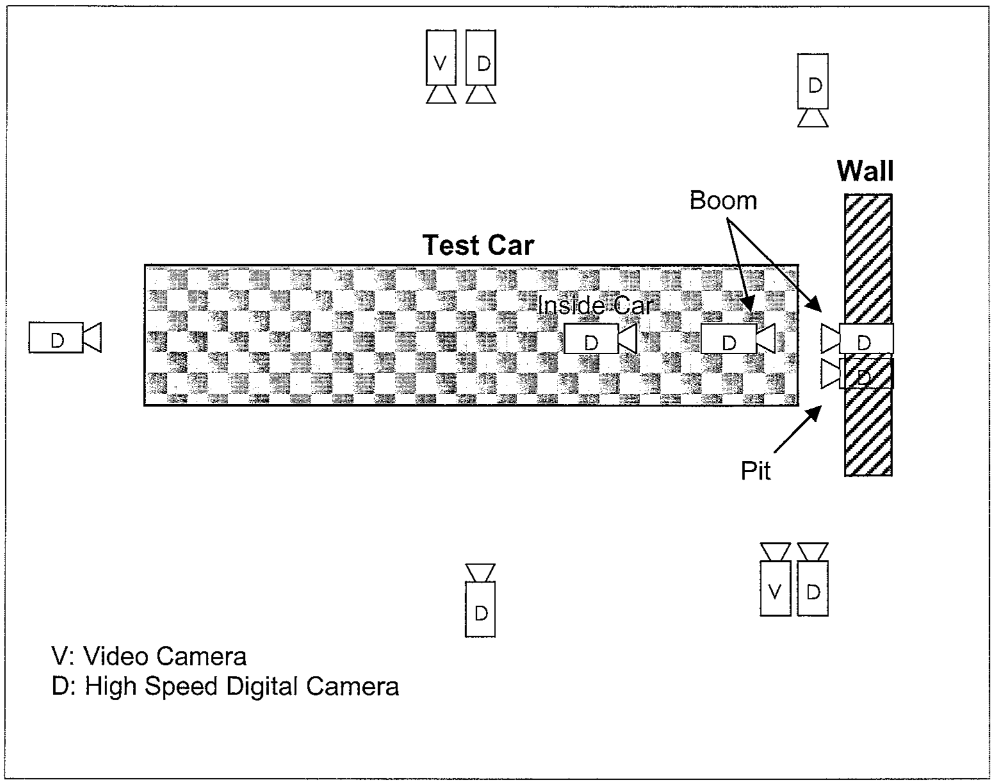


Figure 6. Camera Locations

To assist in the photography analysis, targets were placed on the test car at specified locations. Figures 7 and 8 show an example of target locations.

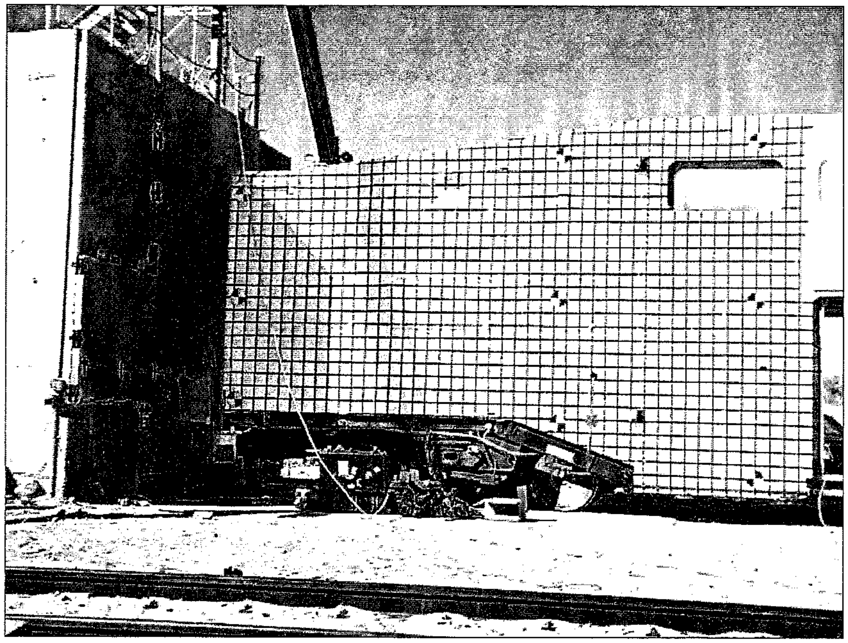


Figure 7. Exterior Target Locations

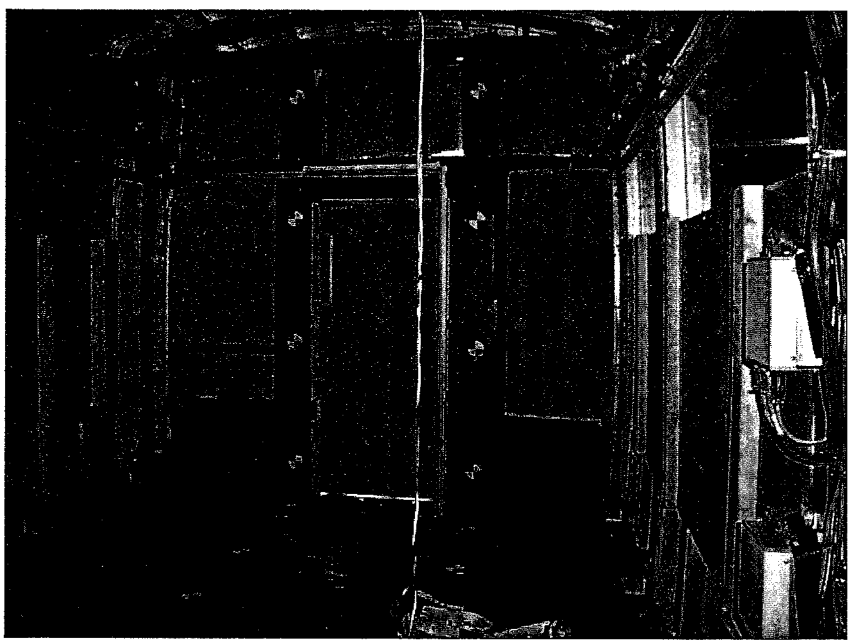


Figure 8. Interior Target Locations

4.8 Post Impact Results

Following the impact test, all video and data were delivered to the FRA. Appendices B through E document the data collected, as indicated in the approved TIP. Longitudinal acceleration data was filtered (CFC=180 Hz) and integrated to determine the velocity as a function of time. Appendix E contains the plots of velocity versus time. The post-test velocities on channels ABCPLX1, ABCPLX2, AL5X, and AR5X were not close to zero, indicating damage to the accelerometer or the electric circuit during the test.

The damage to the vehicle has been documented per a post-test inspection performed by the FRA and its representatives. Figures 9, 10, and 11 illustrate the damage sustained from the impact.

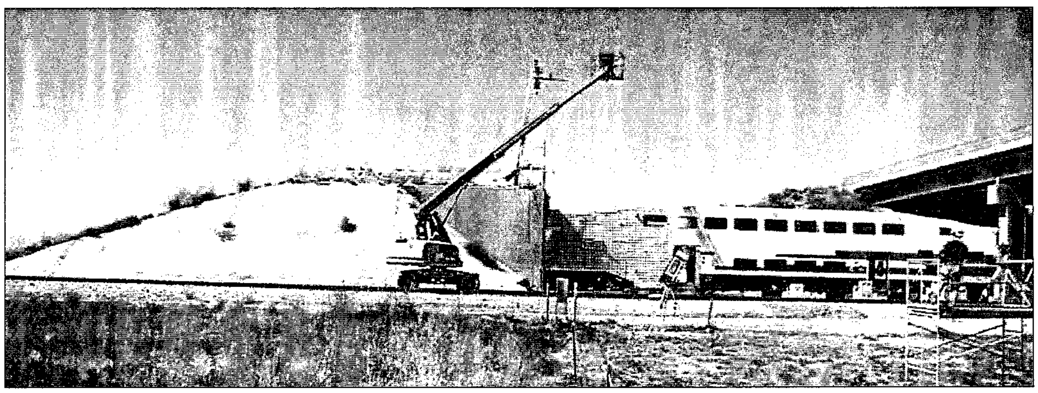


Figure 9. Impact

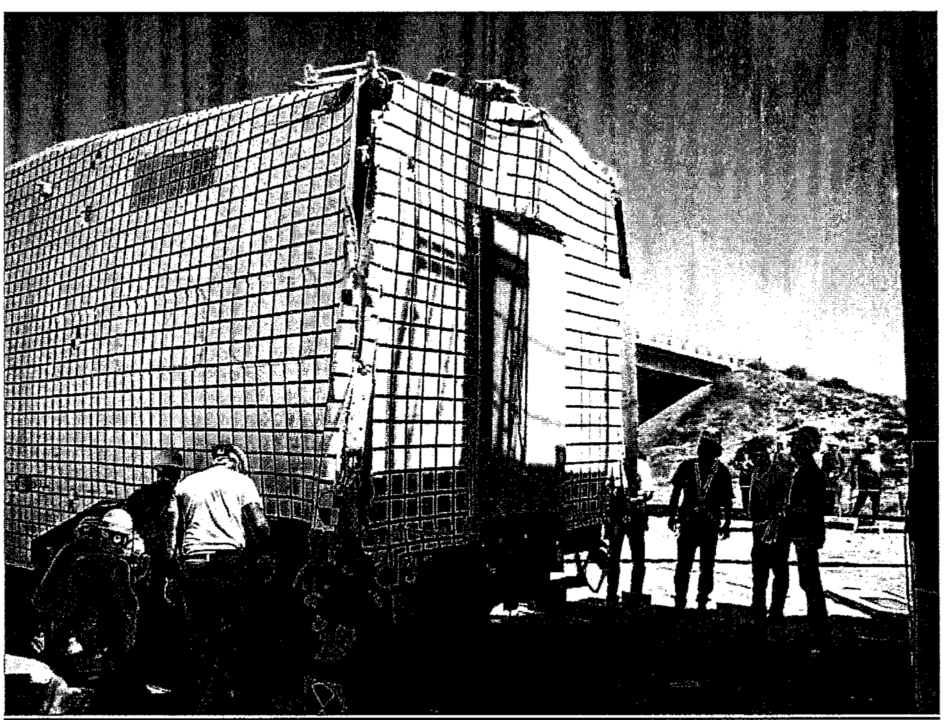


Figure 10. Post Impact End View

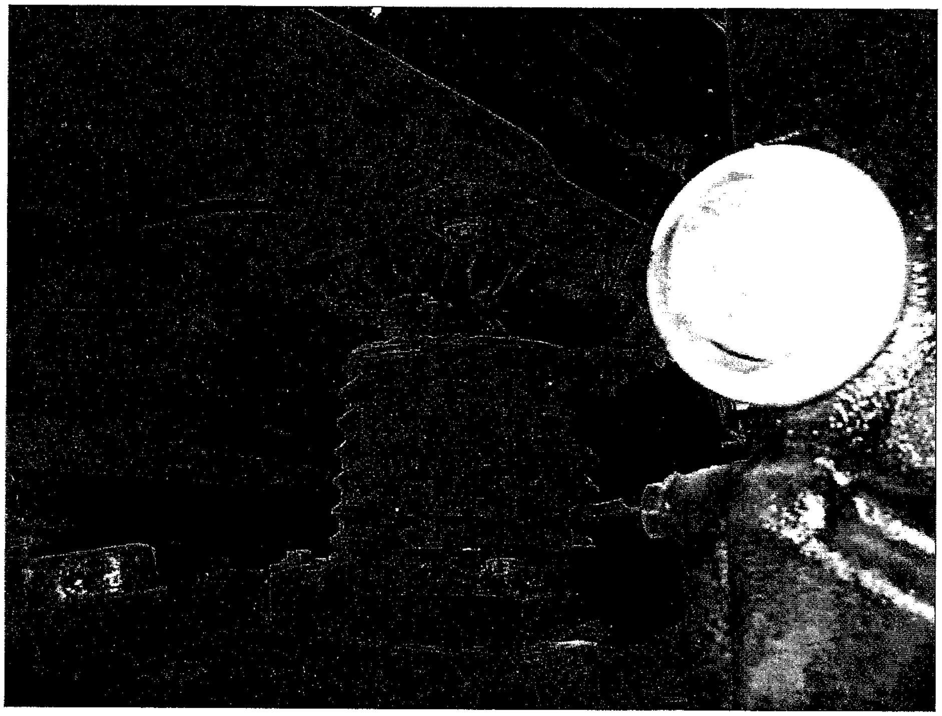


Figure 11. Post Impact Undercarriage View

APPENDIX A.

Test Implementation Plan

Test Implementation Plan for Full Scale Single Car Multi-Level Car Test Impact Test #9

TO 204

(Contract No. DTFR53-00-C-00012)

September 18, 2007
Version 3

Approval _Gunars Spons_ 9-18-07

Gunars Spons — Date
FRA On-Site Contracting Officer's
Technical Representative

Presented by:
Transportation Technology Center, Inc.
55500 DOT Road
P.O. Box 11130
Pueblo, Colorado, USA, 81001

1.0 Purpose

The overall aim of this test is to gather baseline collision performance data on a multilevel commuter rail car. The car is provided by Metrolink and was produced by Bombardier Transit Corporation. The specific objectives are:

- Measure the gross motions of the car (i.e. crash pulse).
- Observe deformation and failure modes of major structural components.
- Measure the gross force-crush characteristic.

2.0 Requirements

This test requires the full scale impact of one multi-level passenger car into a rigid barrier. The intended impact speed is 35 ± 2 mph.

3.0 Test Cars

The test will be conducted using a Generation 1 Bombardier multilevel passenger car.

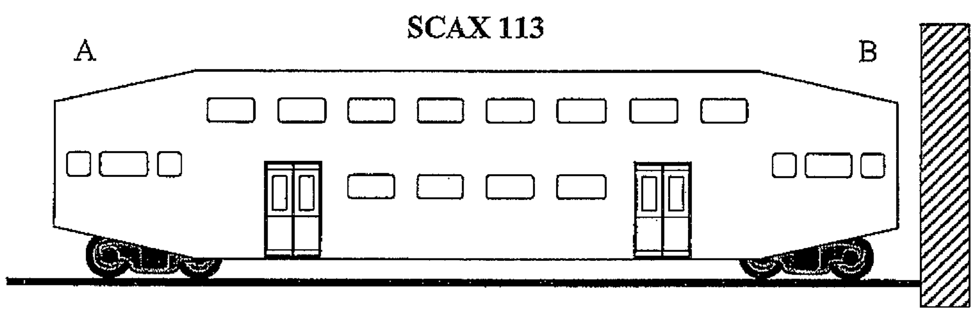


Figure 1: Impact Test Configuration

The coupler on the impact end of the car should be cut in half, flush with the wall.

4.0 Test Method

The impact tests will be performed at TTC by pushing the bullet car with a locomotive. When a pre-defined speed is achieved, the test car will be released from the pushing locomotive, roll along the track, and impact the wall. The distance from the impact point at which the bullet car will be released and the speed of the locomotive at the release point will be determined from a series of speed calibration runs carried out before the test on a track parallel to the impact track. During these speed calibration runs, a radar speed measuring system will be used to precisely measure the speed of the bullet consist. The ambient temperature and wind speed will be measured during the calibration tests and during the impact test. For the impact test, a reflector sensing speed trap will be used to measure the speed of the test consist just before impact.

On-board instrumentation will record accelerations, strains, and displacements at various points on the test car during and after the impact. High-speed video cameras will be used to record the impact test.

5.0 Measured Items

The weight of the test car and the position of all transducers will be measured before the test. Strains and accelerations will be measured during the test using a battery powered on-board data acquisition system which will provide excitation to the strain gages and accelerometers, analog anti-aliasing filtering of the signals, analog-to-digital conversion and recording. Data from each channel will be recorded at a sample rate of 12,800 Hz. All data will be synchronized to a single time reference relative to the time of impact, as determined by the closure of a tape switch on the front of the test car. Data acquisition will be in accordance with SAE J211/1, Instrumentation for Impact Tests (revised March 1995). The following items will be measured during each test:

- The speed of the test car just before impact using a reflector based speed trap (2 channels for redundancy).
- Triaxial acceleration at the center of gravity of the impact car (3 channels).
- Longitudinal and vertical acceleration at the center of the impact car, on each side sill (4 channels).
- Triaxial acceleration near the gooseneck section of the impact car, on the center sill (3 channels).
- Longitudinal and vertical acceleration near the gooseneck section of the impact car, on each side sill (4 channels).
- Triaxial acceleration at the front of the bolster on the center sill, on the impact end of the car (3 channels).
- Longitudinal and vertical acceleration at the front of the bolster on each side sill, on the impact end of the car (4 channels).
- Triaxial acceleration on the rear of the bolster at the center sill (6 channels).
- Longitudinal and vertical acceleration at the rear of each bolster, on each side sill (8 channels).
- Longitudinal and vertical acceleration on one side of each truck (4 channels).
- Longitudinal acceleration on the impact coupler, using two accelerometers (2 channels).
- Longitudinal strains at three locations (two gages at each location) near the impact end of each cant rail. (12 channels).
- Longitudinal strains at three locations (two gages at each location) near the impact end of each side sill. (12 channels).
- Longitudinal strain at three locations (four gages at each location) near the impact end of the center sill. (12 channels).

- Displacement transducers at the top and bottom of each side of the gooseneck section near the impact end of the car (4 channels).
- Displacement transducers across both spring groups of both trucks (4 channels).
- Two displacement transducers on the impact coupler (2 channels).

In summary, 89 channels are required for the test. Redundant channels may be added as deemed appropriate.

Approximately 14 DataBricks will be needed; the exact number will be determined by GMH Engineering. Each Data Brick will be set at a sampling rate of 12,800 Hz and timing of 1 second pre-trigger data collection and 4 seconds of post-trigger data collection.

Exterior views of the impact will be recorded by high-speed digital video cameras backed up by two video cameras. One camera will be used to record an interior view of the impact. The video taken will be referenced to a common time reference so that analysis of the film after the event will give the velocity and displacement of the vehicle and its components during impact.

6.0 Instrumentation

6.1 Acceleration Measurements

Five three-axis accelerometers and ten two-axis (longitudinal and vertical) accelerometers will be used to measure the gross and flexible motion of the car body during the impact test. In addition, the motion of each truck will be measured with a two-axis accelerometer.

All the accelerometers are critically damped. The accelerometers will be calibrated prior to installation. The accelerometers possess natural frequencies sufficiently high to meet the requirements of SAE J211/1, *Instrumentation for Impact Test (Revised MAR95)*, Class 1000, which requires that the frequency response is essentially flat to 1000 Hz.

Table 1 lists the accelerometer locations, accelerometer types, and data channel names.

Table 1: Accelerometer Parameters

End	Side	Location	X-Longitudinal	Y-Lateral	Z-Vertical	Range
-	-	Approximate CG	A_CG_X	A_CG_Y	A_CG_Z	200G
-	L	Approximate CG	A_CG_L_X	A_CG_L_Y		200G
-	R	Approximate CG	A_CG_R_X	A_CG_R_Y		200G
B	-	Impact Gooseneck	A_GN_X	A_GN_Y	A_GN_Z	200G
B	L	Impact Gooseneck	A_GN_L_X	A_GN_L_Y		200G
B	R	Impact Gooseneck	A_GN_R_X	A_GN_R_Y		200G
A	-	Rear Bolster	A_BR_A_X	A_BR_A_Y	A_BR_A_Z	200G
A	L	Rear Bolster	A_BR_AL_X	A_BR_AL_Y		200G
A	R	Rear Bolster	A_BR_R_X	A_BR_AR_Y		200G
B	-	Rear Bolster	A_BR_B_X	A_BR_B_Y	A_BR_B_Z	200G

B	L	Rear Bolster	A_BR_BL_X	A_BR_BL_Y		200G
B	R	Rear Bolster	A_BR_R_X	A_BR_BR_Y		200G
B	-	Front Bolster	A_BF_B_X	A_BF_B_Y	A_BF_B_Z	200G
B	L	Front Bolster	A_BF_BL_X	A_BF_BL_Y		200G
B	R	Front Bolster	A_BF_R_X	A_BF_BR_Y		200G
B	-	Coupler	A_CPL_1_X			5000G
B	-	Coupler	A_CPL_2_X			5000G
A	-	Truck	A_TK_A_X	A_TK_A_Y		400G
B	-	Truck	A_TK_B_X	A_TK_B_Y		400G

6.2 Strain Measurements

Figures 1 and 2 show the general arrangement of strain gauges on the car sides and center sill. Table 2 lists the locations and strain gauge types for the car sides and Table 3 lists the locations and strain gauge types for the center sill.

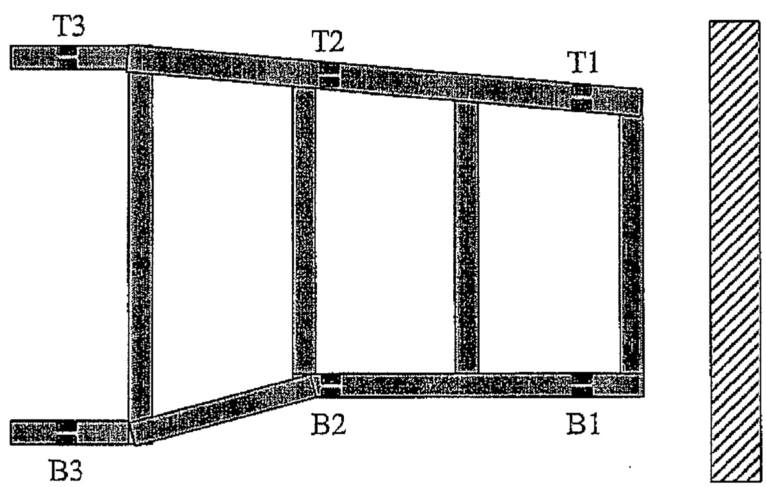


Figure 2: Strain Gage Location -- Car Sides (Impact End)

Table 2: Strain Gage Parameters -- Car Sides (Impact End)

Side	Location	Channel Name	Strain Gauge Type
Left	T1	S_LS_T1	Standard
Left	T2	S_LS_T2	Standard
Left	T3	S_LS_T3	Standard
Left	B1	S_LS_B1	Standard

Left	B2	S_LS_B2	Standard
Left	B3	S_LS_B3	Standard
Right	T1	S_RS_T1	Standard
Right	T2	S_RS_T2	Standard
Right	T3	S_RS_T3	Standard
Right	B1	S_RS_B1	Standard
Right	B2	S_RS_B2	Standard
Right	B3	S_RS_B3	Standard

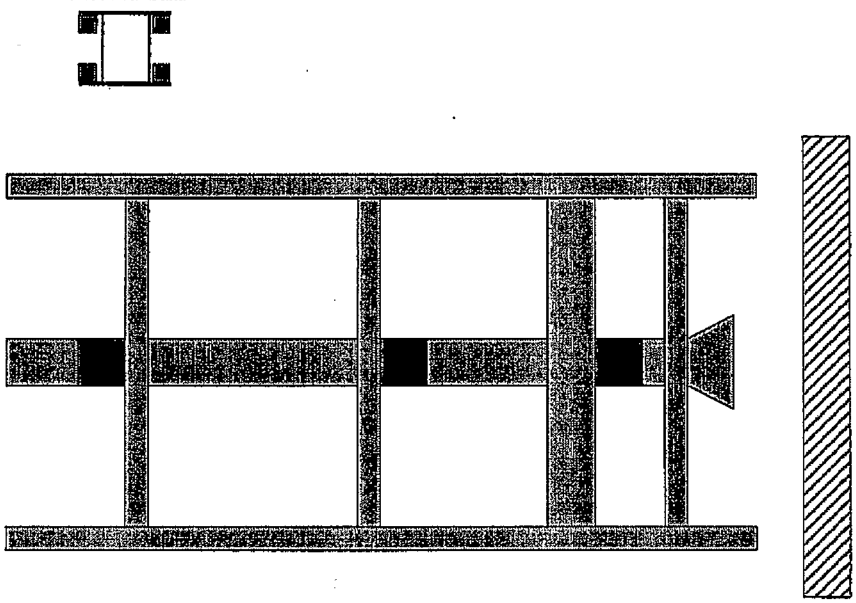


Figure 3: Strain Gage Locations -- Center Sill (Impact End)

Table 3: Strain Gage Parameters -- Center Sill (Impact End)

Location	Channel Name	Strain Gauge Type
Rear Bolster	S_CS_BR_TL	Standard
Rear Bolster	S_CS_BR_TR	Standard
Rear Bolster	S_CS_BR_BL	Standard
Rear Bolster	S_CS_BR_BR	Standard
Front Bolster	S_CS_BF_TL	Standard

Front Bolster	S_CS_BF_TR	Standard
Front Bolster	S_CS_BF_BL	Standard
Front Bolster	S_CS_BF_BR	Standard
Gooseneck	S_CS_GN_TL	Standard
Gooseneck	S_CS_GN_TR	Standard
Gooseneck	S_CS_GN_BL	Standard
Gooseneck	S_CS_GN_BR	Standard

6.3 Displacement Measurements

Displacements during the impact will be measured by four displacement transducers across the gooseneck section on the impact end of the car, one displacement transducer across each spring group, and two displacement transducers on the impact coupler. Figure 4 depicts the approximate locations of these transducers. Table 4 gives the string potentiometer ranges and channel names.

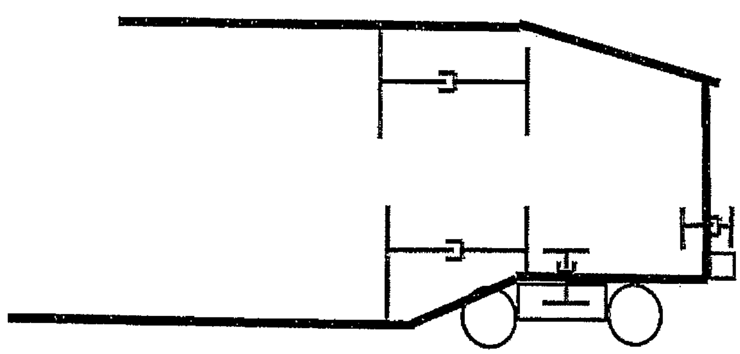


Figure 4: Displacement Transducer Locations

Table 4: String Potentiometer Parameters

End	Side	Location	Channel Name	Range
B	Left	Impact Gooseneck	D_GN_TL	20 in
B	Left	Impact Gooseneck	D_GN_BL	20 in
B	Right	Impact Gooseneck	D_GN_TR	20 in
B	Right	Impact Gooseneck	D_GN_BR	20 in

A	Left	Spring Group	D_SG_AL	10 in
B	Left	Spring Group	D_SG_BL	10 in
A	Right	Spring Group	D_SG_AR	10 in
B	Right	Spring Group	D_SG_BR	10 in
B	-	Coupler	D_CPL_X	20 in
B	-	Coupler	D_CPL_Y	20 in

6.4 High-Speed and Real-Time Photography

Nine high-speed digital cameras and two video cameras will document the impact test. The positions of these cameras are shown in Figure 5. One camera is located in a pit under the impact area; if possible, this pit may be dug deeper to accommodate the camera. Battery powered on-board lights will illuminate the on-board camera view.

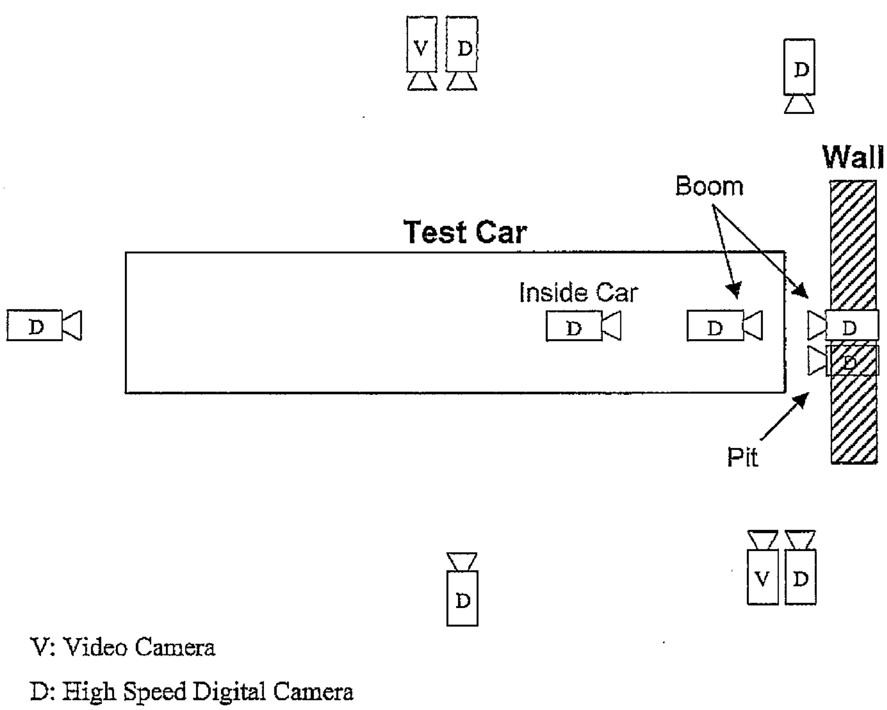


Figure 5: Camera Locations

The final sighting of cameras will be carried out at the time of camera setup. Adjustments will be made, if necessary, to achieve the optimum views. Exact locations may be adjusted to account for conditions on the day of test.

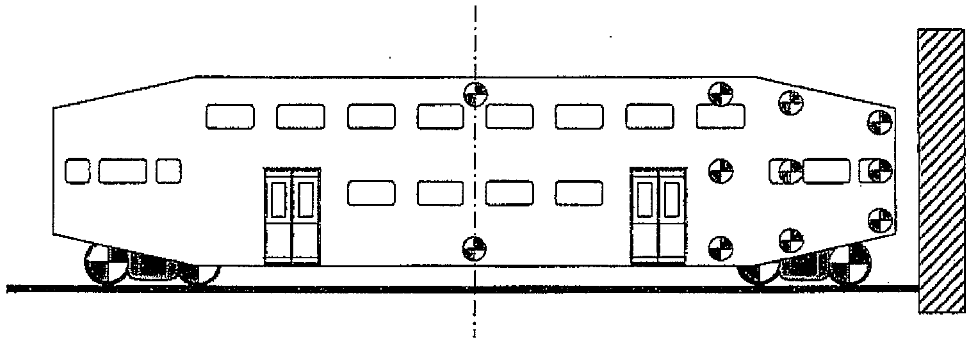


Figure 6: Target Locations

Targets will be placed on the test car to facilitate post-test film analysis to determine speed and displacement during the test. The targets are divided into four quadrants with adjacent colors contrasting for good visibility. Eight-inch diameter targets will be used at the locations specified in Figure 6. Additionally, targets will be painted on the wheels of the test car. The distances between the targets, which are known from pre-test measurements, provide distance reference information for the film analysis. Video from all cameras will be referenced to a common time standard.

6.5 Data Acquisition

A set of 8-channel battery-powered on-board data acquisition systems will provide excitation to the strain gauges, accelerometers and displacement transducers, analog anti-aliasing filtering of the signals, analog-to-digital conversion, and recording.

Data acquisition will be in compliance with SAE J211. Data from each channel will be recorded at 12,800 Hz. Parallel redundant systems will be used for all accelerometer channels. Data recorded on the Data Bricks will be synchronized with a time reference applied to all systems simultaneously at the time of impact. The time reference will come from closure of the tape switches on the front of the test vehicle. The data acquisition systems are GMH Engineering Data Brick Model II. Each Data Brick is ruggedized for shock loading up to at least 100 g. On-board battery power will be provided by GMH Engineering 1.7 A-HR 14.4 volt NiCad Packs. Tape Switches, Inc., model 1201-131-A tape switches will provide event markers.

Software in the Data Brick will be used to determine zero levels and calibration factors rather than relying on set gains and expecting no zero drift. The Data Bricks will be set to record 1 second of pre-trigger data and 4 seconds of post-trigger data.

6.6 Speed Trap

A dual channel speed trap will accurately measure the impact speed of the locomotive when it is within 0.5 meter of the impact point. The speed is a reflector based sensor developed at TTC which uses two ground based reflectors separated by a known distance and a train based reflector sensor that triggers as the vehicle passes over the reflectors. The interval between interruptions is recorded by a DataBrick, and the speed can then be derived from distance and time. Final location of the reflector sensor will be determined prior to installation. Redundant speed measurement will be made with a handheld radar gun.

7.0 Test Procedure

- The video cameras will be set up as per Figure 5.
- The test car will be at the site the day before testing to check camera views and check alignment of equipment, including tape switches.
- The weight of the test car will be measured before the test.
- All instruments will be zeroed.
- The test car will be pulled back.
- The test car will be pushed by a locomotive and released at the appropriate distance from the impact wall. Cameras will be triggered just before impact.
- The instrumentation will be triggered on impact.
- Visual inspection will be carried out after impact. Still photographs will be taken.
- The data will be downloaded from the on-board data acquisition system onto laptop computers.
- A checklist based on the above tasks will be signed by key personnel as each task is completed. A copy of this checklist is provided in section 10.0.

8.0 Data Analysis

8.1 Data Post-Processing

Each data channel will be offset adjusted in post-processing. The procedure is to average the data collected just prior to the impact between the test car and the impact wall and subtract the offset from the entire data set for each channel. It is expected that between 0.05 and 1.0 second of pre-impact data will be averaged to determine the offsets. The precise duration of the averaging period cannot be determined with certainty until the data are reviewed. The offset adjustment procedure assures that the data plotted and analyzed contains impact-related accelerations and strains but not electronic offsets or steady biases in the data. The post-test offset adjustment is independent of, and in addition to, the pre-test offset adjustment made by the data acquisition system.

Plots of all recorded data channels and combinations of data channels will be produced as described below. Post-test filtering of the data will be accomplished with a two-pass phaseless four-pole digital filter algorithm consistent with the requirements of SAE J211. In the filtering process, data are first filtered in the forward direction with a two-pole filter. The first pass of the filtering process introduces a phase lag in the data. In the next pass, the data are filtered in the reverse direction with the same filter. Because the data are filtered in the reverse direction, a phase lead is introduced into the data. The phase lead of the reverse-direction filtering cancels the phase lag from the forward-direction filtering. The net effect is to filter the data without a change in phase with a four-pole filter.

8.2 Data Presentation

Every channel as recorded (raw data) will be plotted against time (where time = 0 is defined as the impact of the test car with the impact wall).

The acceleration records during the impacts will be plotted against time. The longitudinal acceleration will be integrated and the derived velocity plotted against time. The strain gauge time histories will be presented.

All data recorded by the Data Bricks, the derived values mentioned above, and plotted time histories will be presented to the FRA in digital form on a CD.

All data from the video cameras, the high speed video camera, and the high speed film cameras will be transferred to DVD.

9.0 Safety

All Transportation Technology Center, Inc. (TTCI) safety rules will be observed during the preparation and performance of the crash tests. All personnel participating in the tests will be required to comply with these rules when visiting the TTC, including wearing appropriate personal protective equipment. A safety briefing for all test personnel and visitors will be held prior to testing.

10.0 Detailed Schedule

The schedule for the day of test is planned as follows.

Time	Event
8:00	Meet @ JRF for briefing status
8:30	Move Test Consist from JRF to impact site
9:00	Instrumentation Prep at impact point
	Camera Prep at impact point
	Pre-Test Photographs at impact point
	Pre-Test Predictions @ Harris Hall (Volpe)
10:00	Pull back consist to starting position
	Instrumentation Prep
	Camera Prep
10:30	Spectators convene at Impact site
11:00	Impact Test
11:10 – 4:00	Post-Test documentation and clean-up

A day of test check-off sheet will be implemented to ensure that key members of the test team are ready for test. A copy of this sheet is shown below.

Multi-Level Car Test – Day of Test Checklist

1	AM Site Prep (dust control).	Guerrero	
2	Measure wind speed and ambient temperature	GM	
3	Make sure all observers are in a safe position - check with Safety Officer	Floyd/Terry/Luis	
4	Instruct observers to remain quiet during test and that you will notify them when they can talk	Floyd/Terry/Luis	
5	Ensure that the track is free and clear	GM	
6	Check with photographer that everything OK	GM	
7	Check with GMH Engineer that all instrumentation modules are activated, zeroed and ready to trigger	GM	
8	Check with TTCI Project Engineer (Witte) for test readiness	GM	
9	Check with FRA Project Engineer (Gunars) for test readiness	GM	
10	Check that PTT turnout is lined and spiked	GM	
11	Verify Test Car Inspection Checklist is completed	GM	
13	Check with locomotive engineer for test readiness	GM	
14	Clearance from Safety Officer (Terry) to start the test	GM	
15	Give instructions to locomotive engineer to release test car	GM	
16	Check with Jerry McIntyre when spectators can speak	Floyd	
17	Check stability of vehicle after impact	White	
18	Check exterior of vehicle	Keith/Gunars	
20	GMH to download information from Data Bricks	J. Gordon	
21	Measure and record post-test position of car	White	
22	Take photographs of test vehicle, instrumentation	Witte/Williams	

11.0 Key Personnel and Responsibilities

The following individuals will participate as part of the Test Team from TTCI.

Matthew Witte – Project Manager,

Matt will be responsible for the overall execution of the test, including planning and oversight of all of the tasks. Matt will also serve as liaison between TTCI and the FRA, their sub-contractors, and visitors.

Greg McBride – Test Controller,

Greg will be responsible for the day-to-day operations and logistics for the test including safety. Greg will serve as the point of contact for the test team.

Dave Williams – Instrumentation,

Dave will be responsible for coordinating all of the instrumentation needs for the test, including those being supported by TTCI's sub-contractor, GMH Engineering. Dave will retain the appropriate paper trail for the instrumentation efforts.

Supplemental Information

Change Log

Version 2: Aug 31, 2007

1) Corrected sum total number of data channels from 91 to 93 to reflect the two speed channels.

2) Added "Figure 4. Displacement Transducer Locations" and renumbered figures and references in the text.

3) Added values for displacement transducer ranges in Table 4.

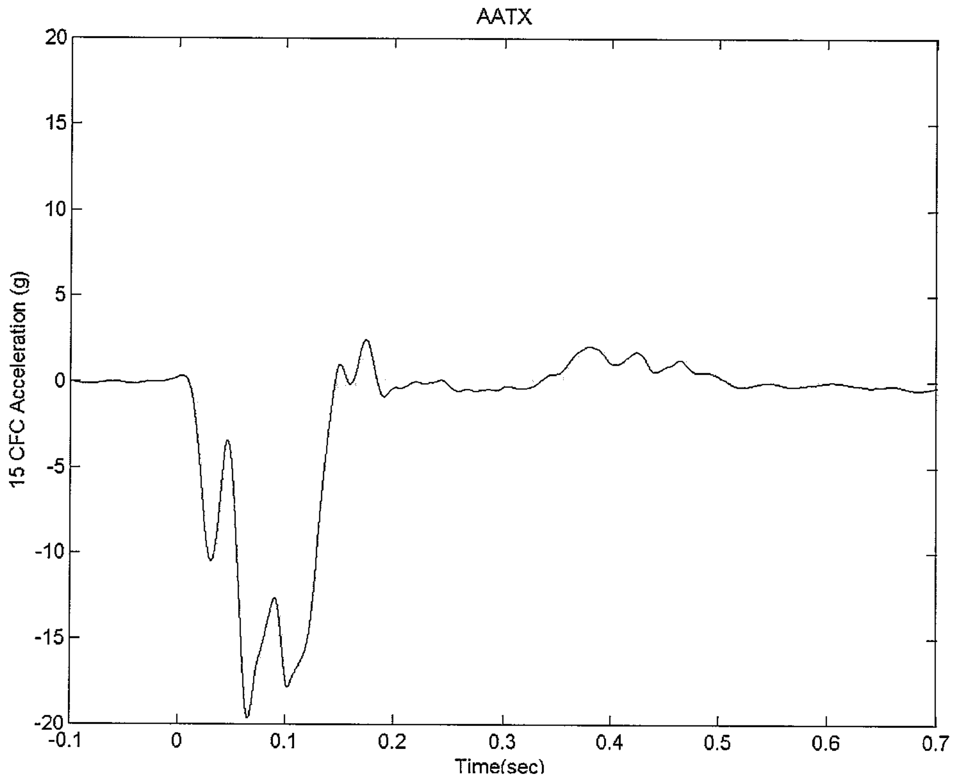
4) Changed range values for coupler accelerometers in Table 1 (from 400g to 5000 g).

Version 3: September 18, 2007

1) Corrected reference name of car from bilevel to multilevel
2) Eliminated reference to specific crash event.
3) Eliminated requirement for vertical and lateral accelerations on the impact coupler.

APPENDIX B.

Acceleration Plots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-5
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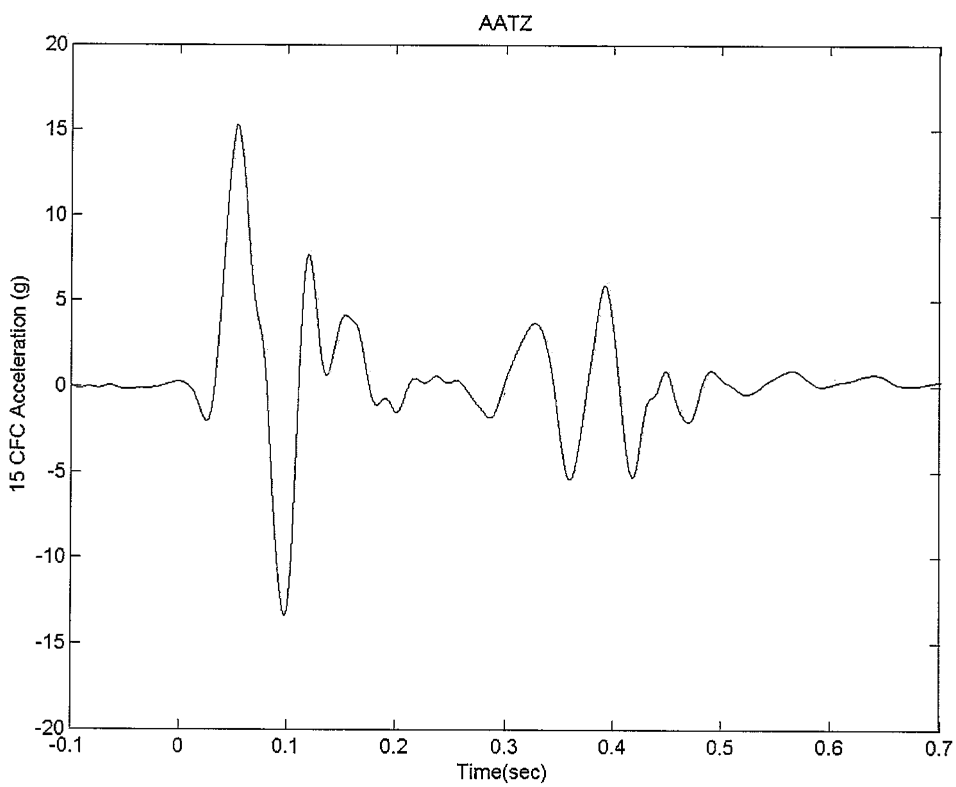
0.3
0.4
0.5
0.6
0.7
Time(sec)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20
15
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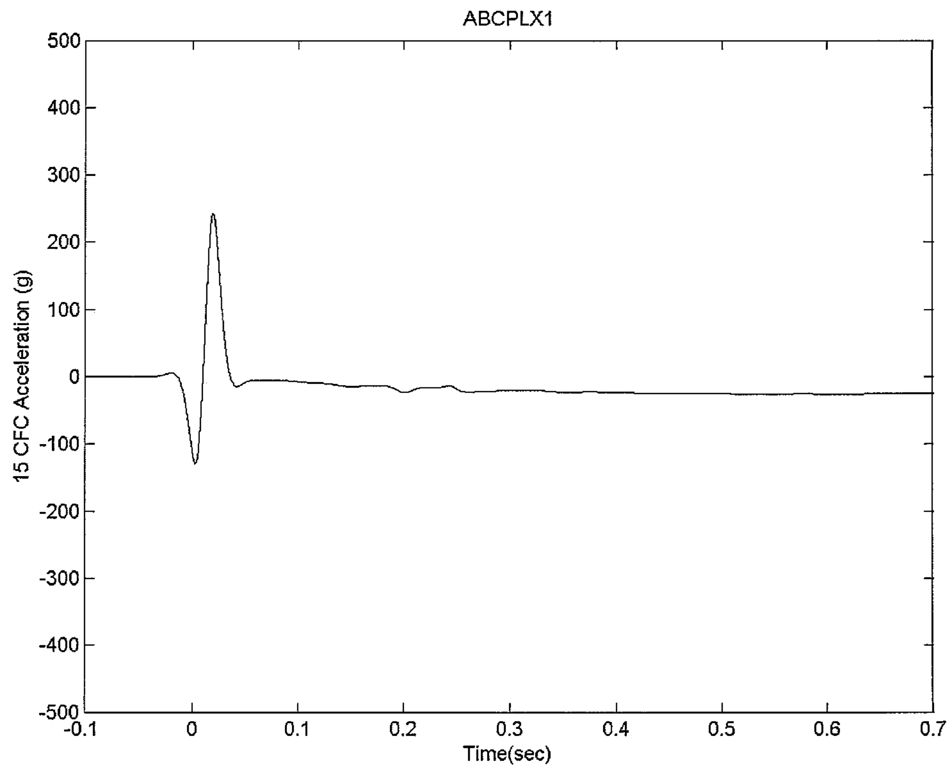
Time(sec)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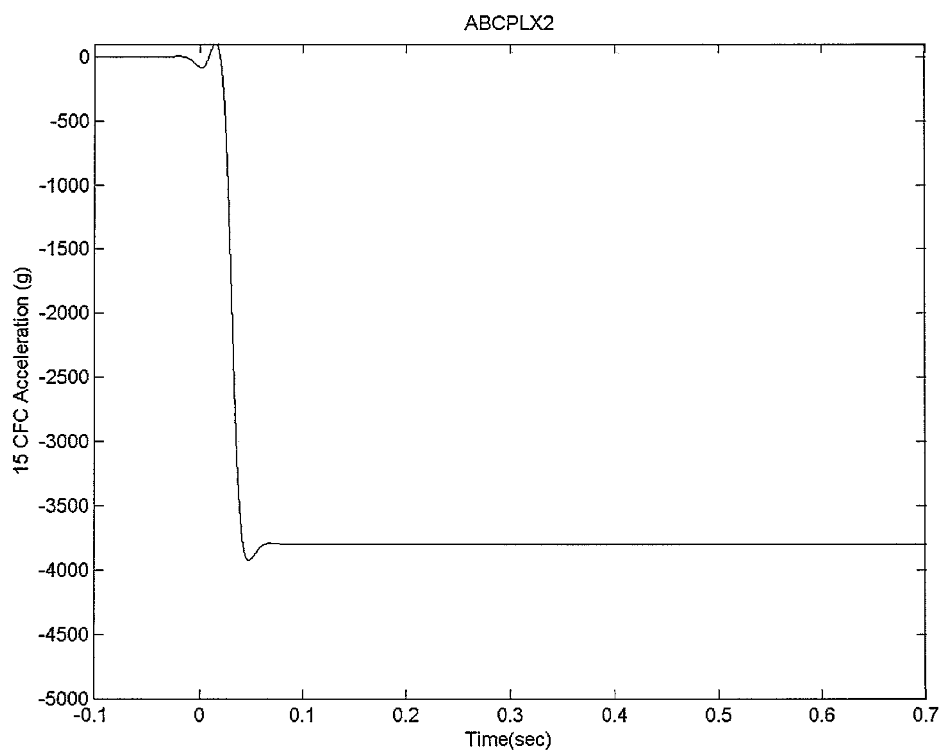
0.3
0.4
0.5
0.6
0.7
Time(sec)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0.5
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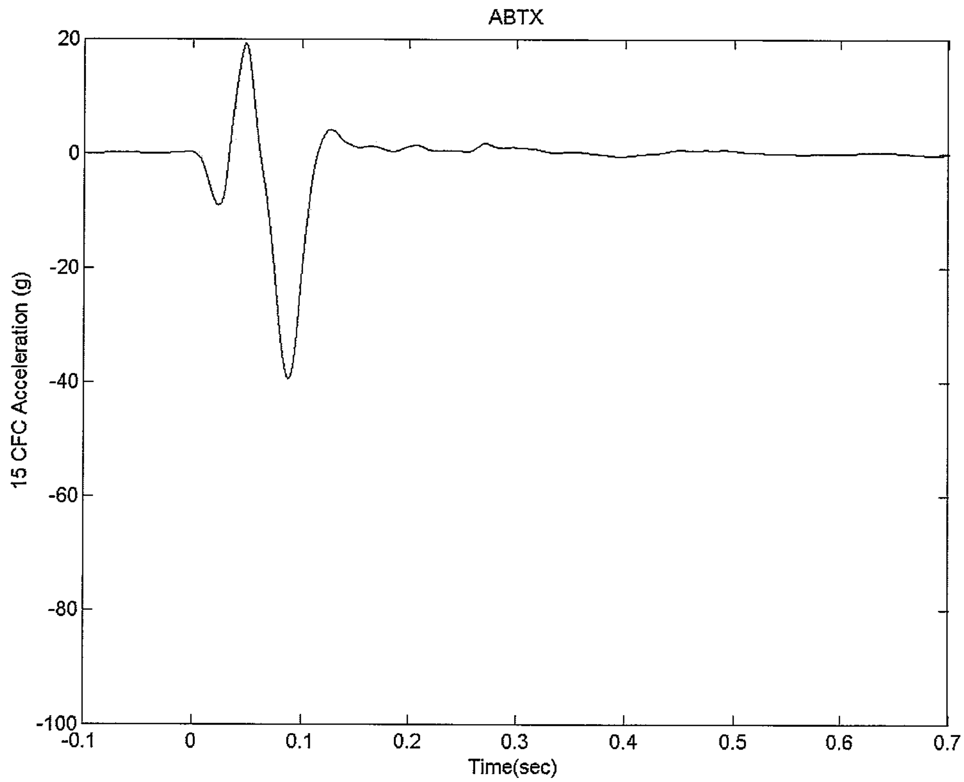
Time(sec)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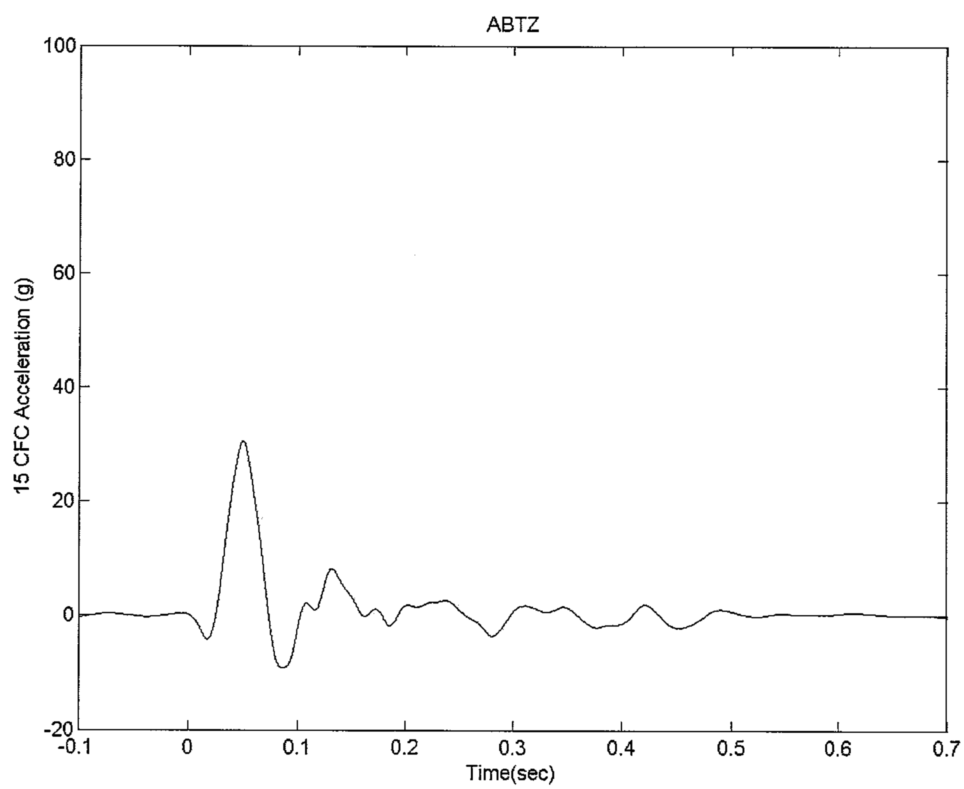
0.6
0.7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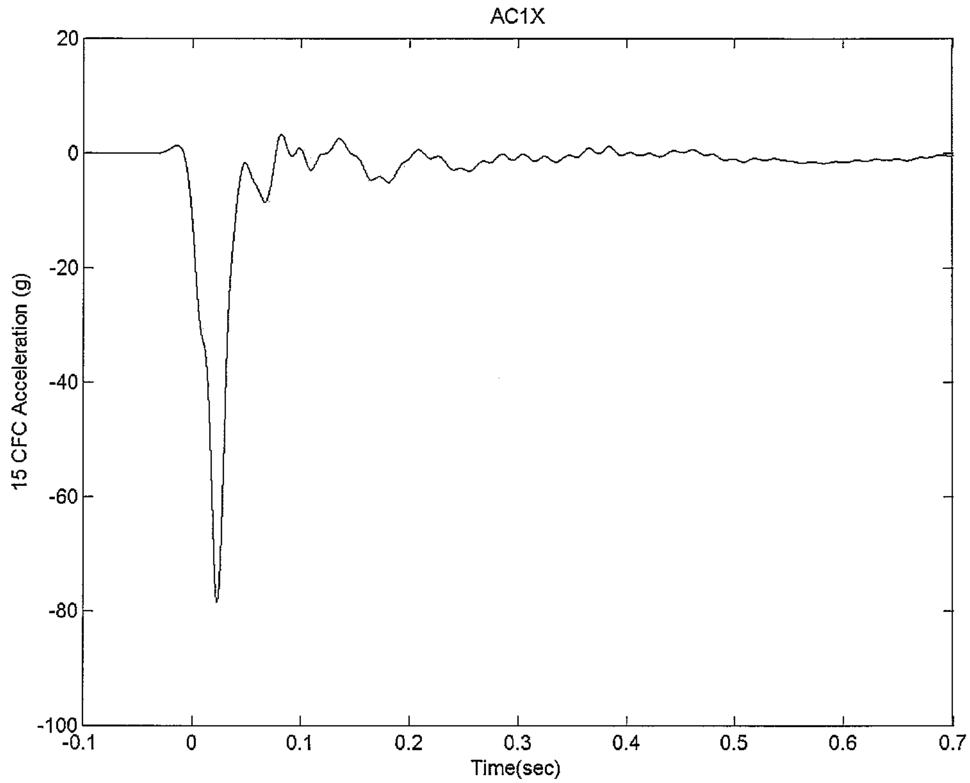
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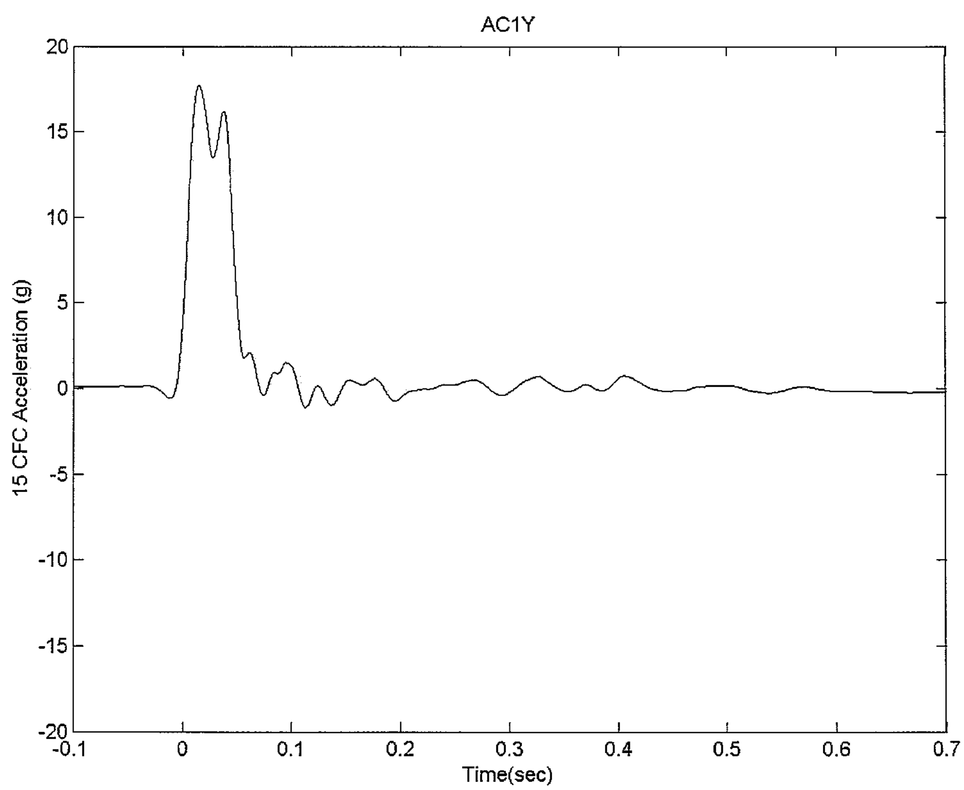
Time(sec)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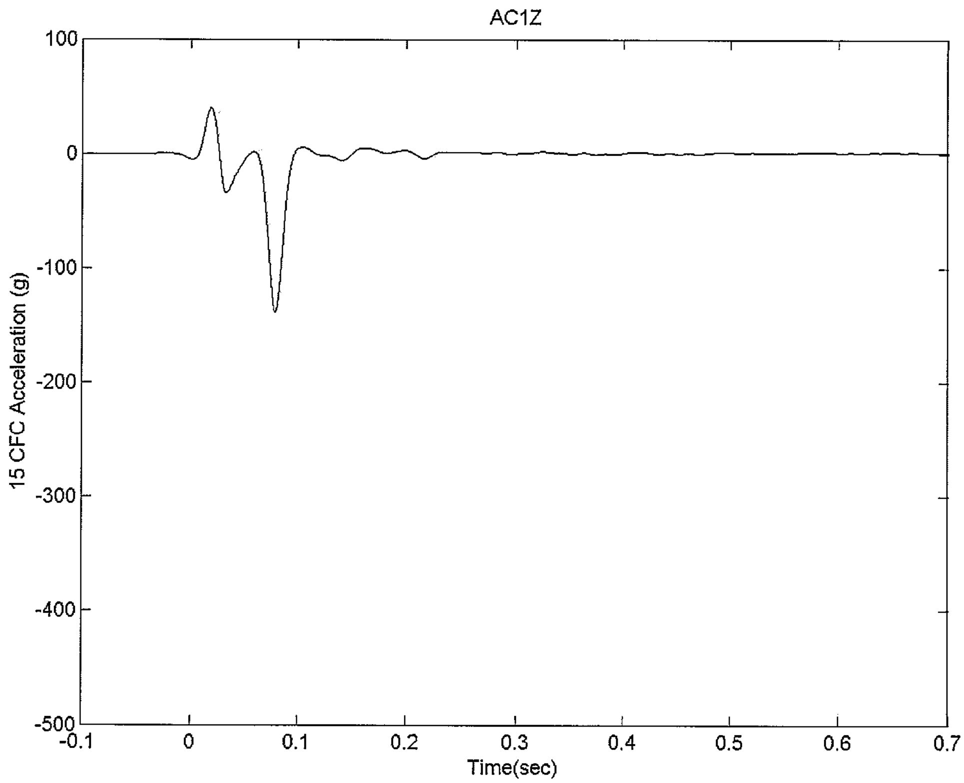
Time(sec)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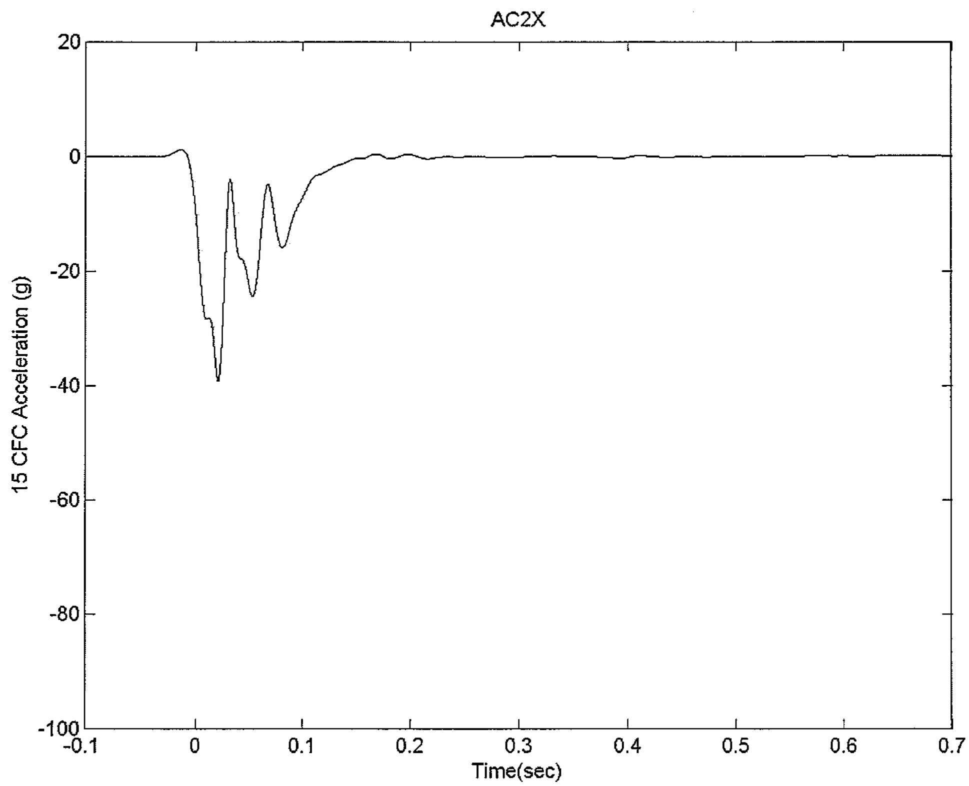
0.7
Time(sec)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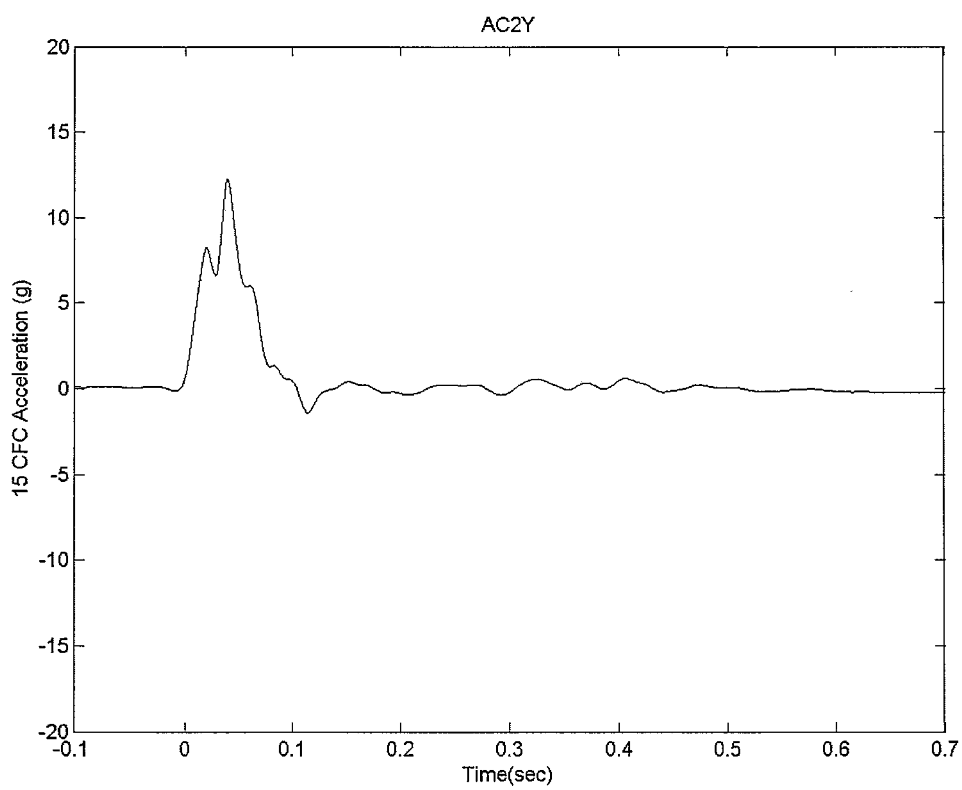
0.6
0.7
Time(sec)
15 CFC Acceleration (g)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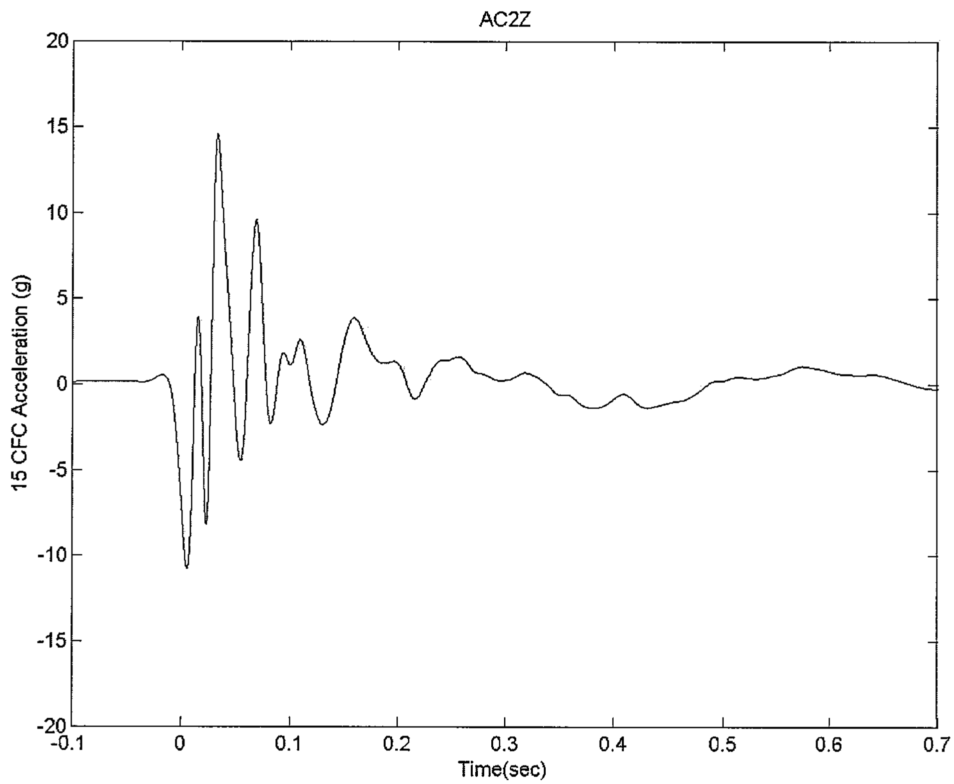
0.5
0.6
0.7
Time(sec)
15 CFC Acceleration (g)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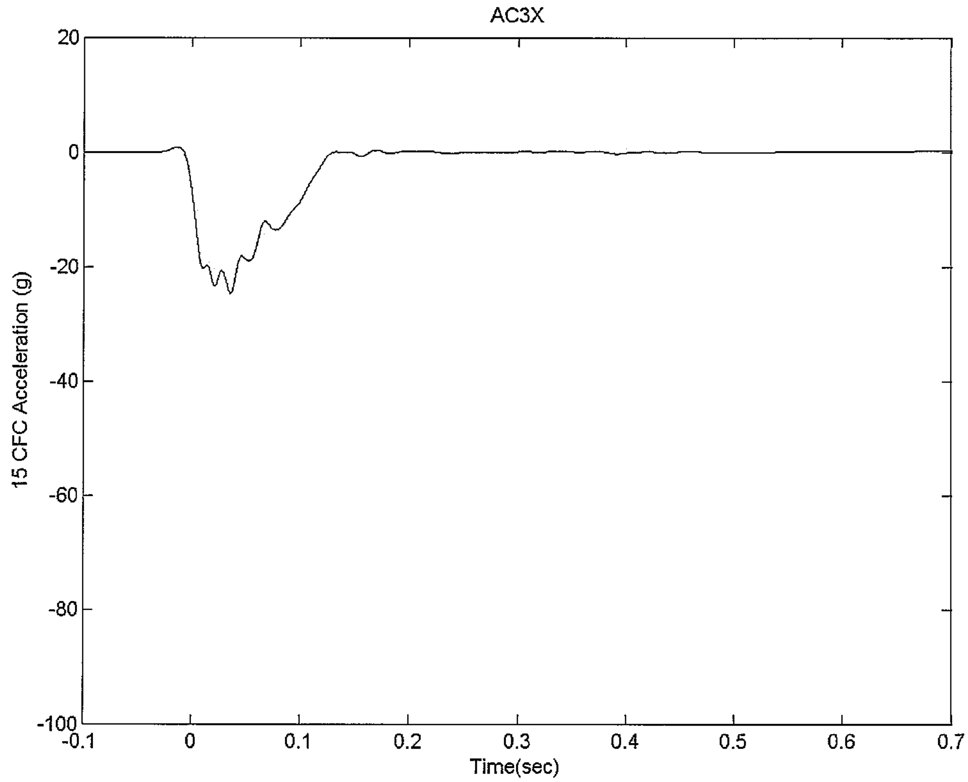
Time(sec)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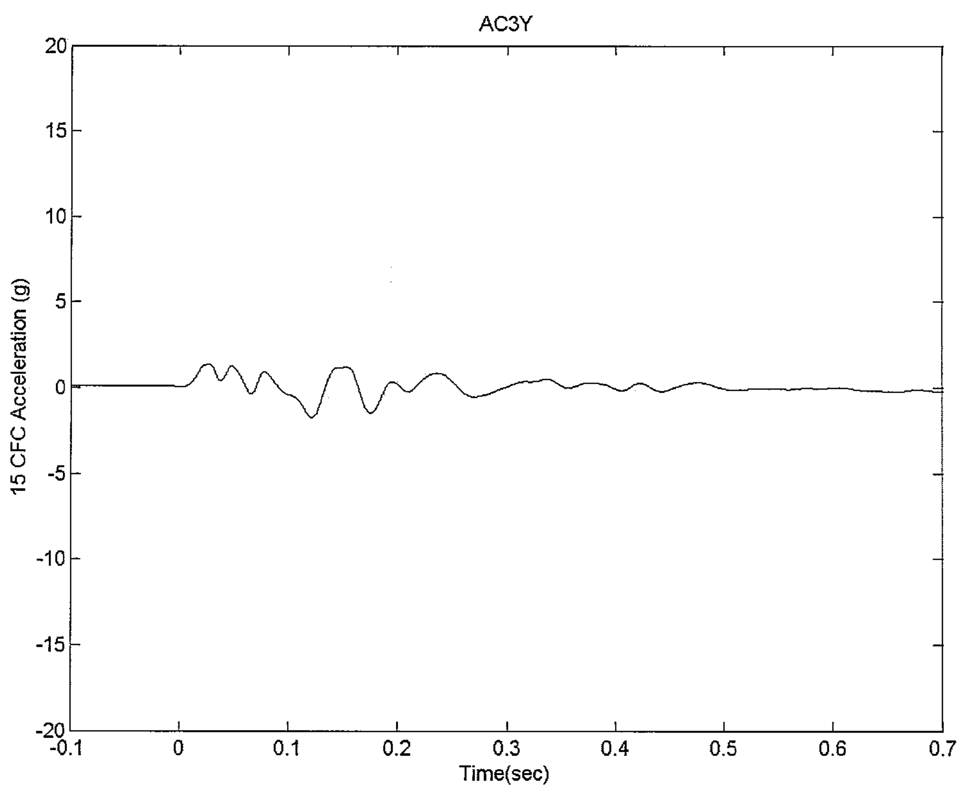
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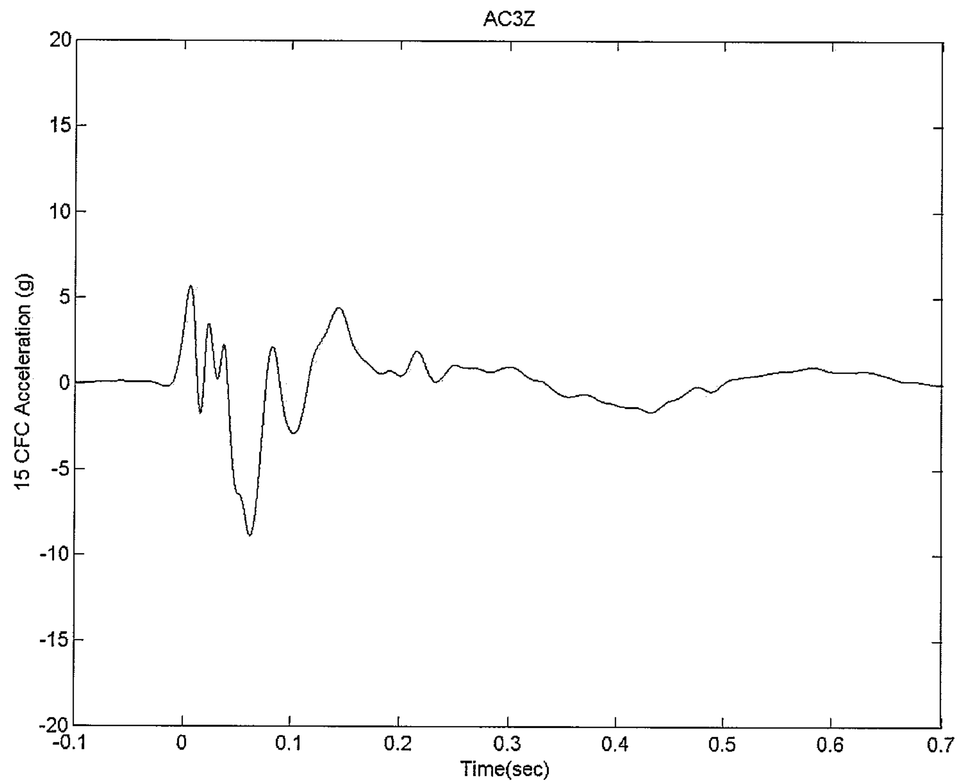
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0.4
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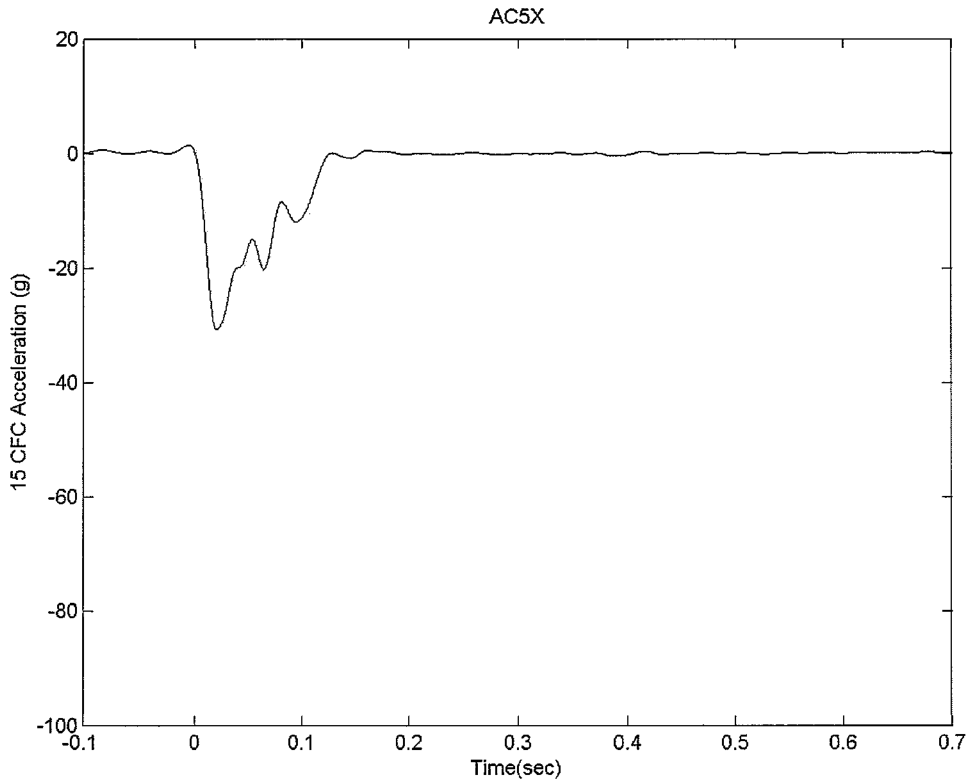
Time(sec)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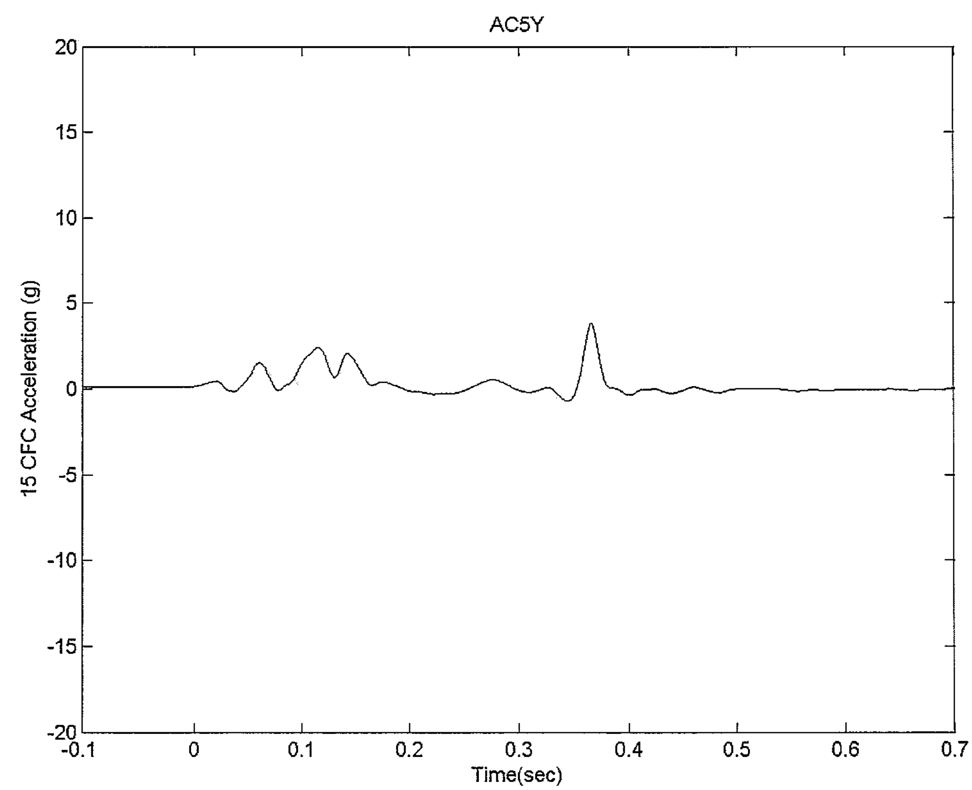
Time(sec)
15 CFC Acceleration (g)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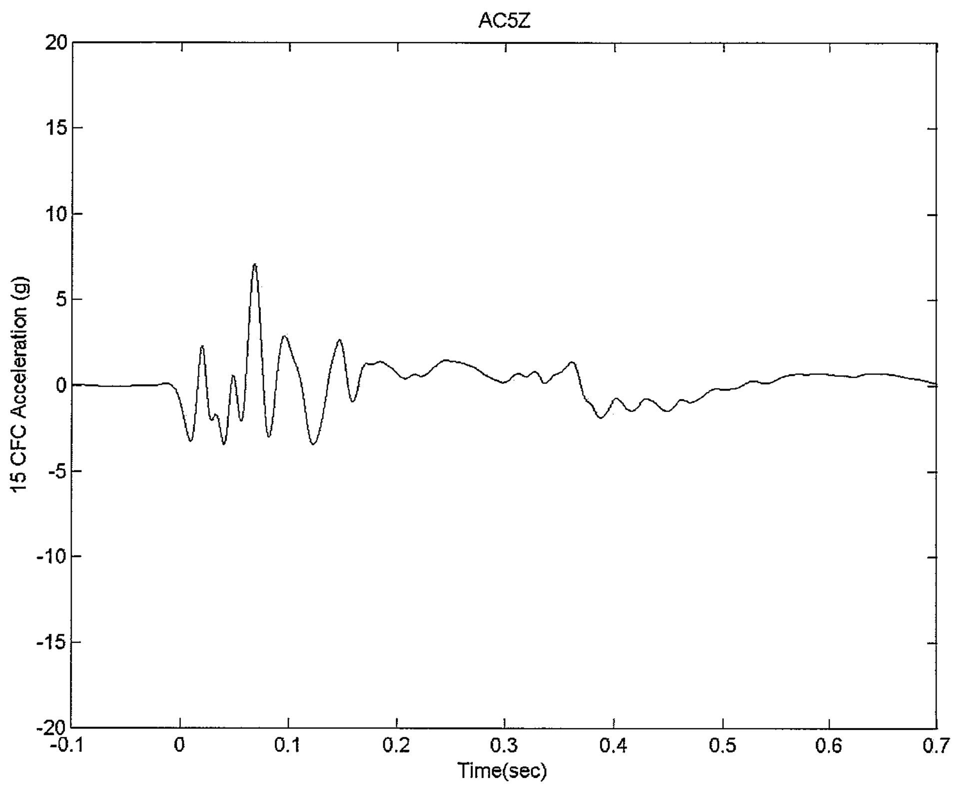
0.5
0.6
0.7
Time(sec)
15 CFC Acceleration (g)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0.4
0.5
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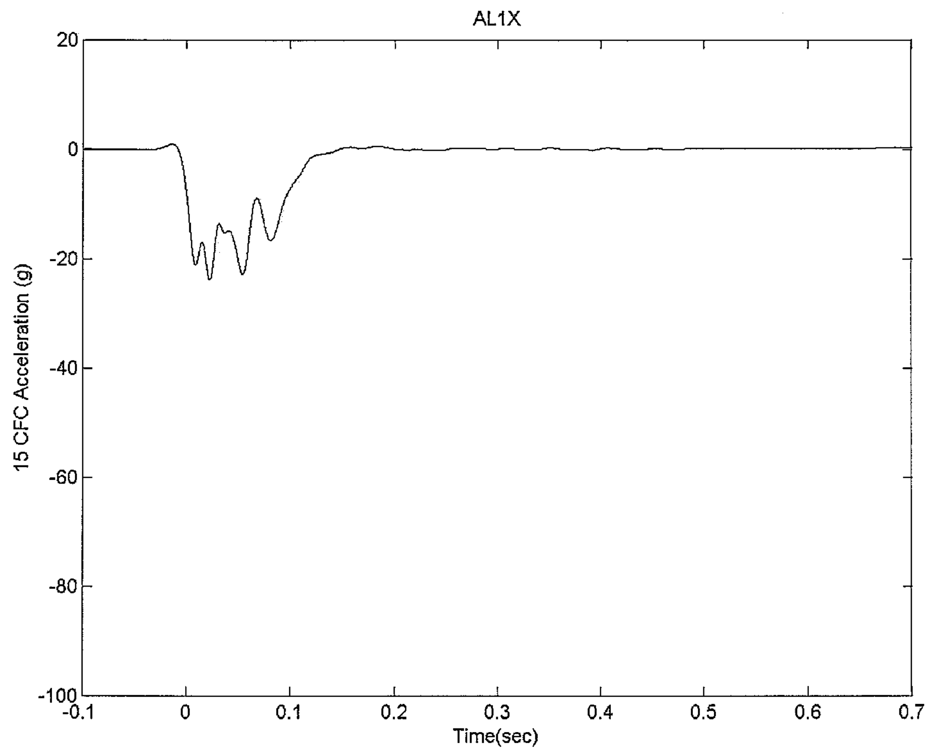
Time(sec)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Time(sec)
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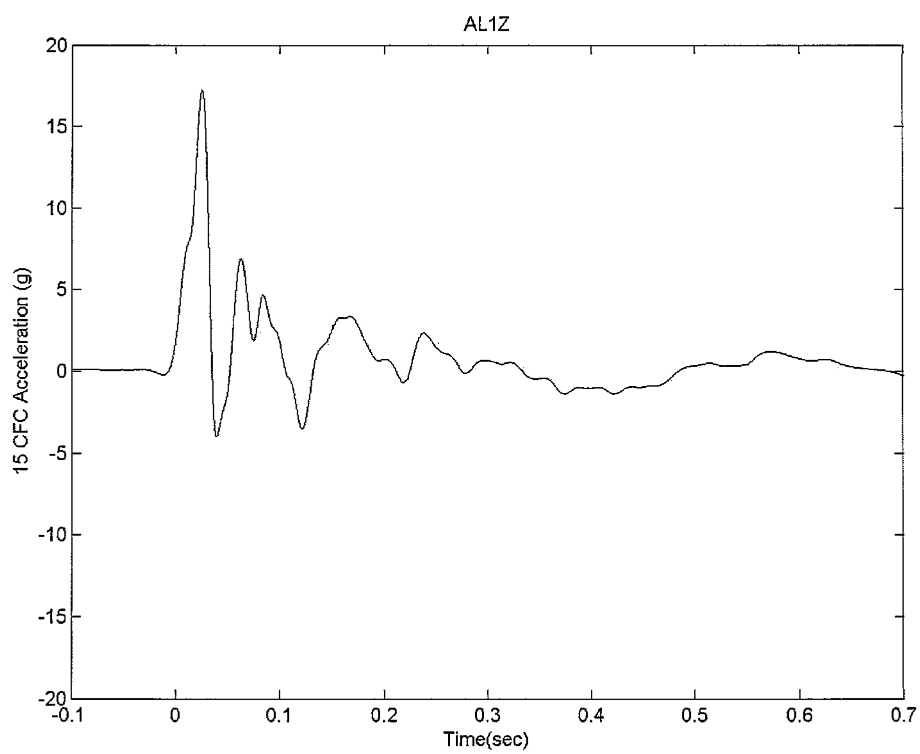
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Time(sec)
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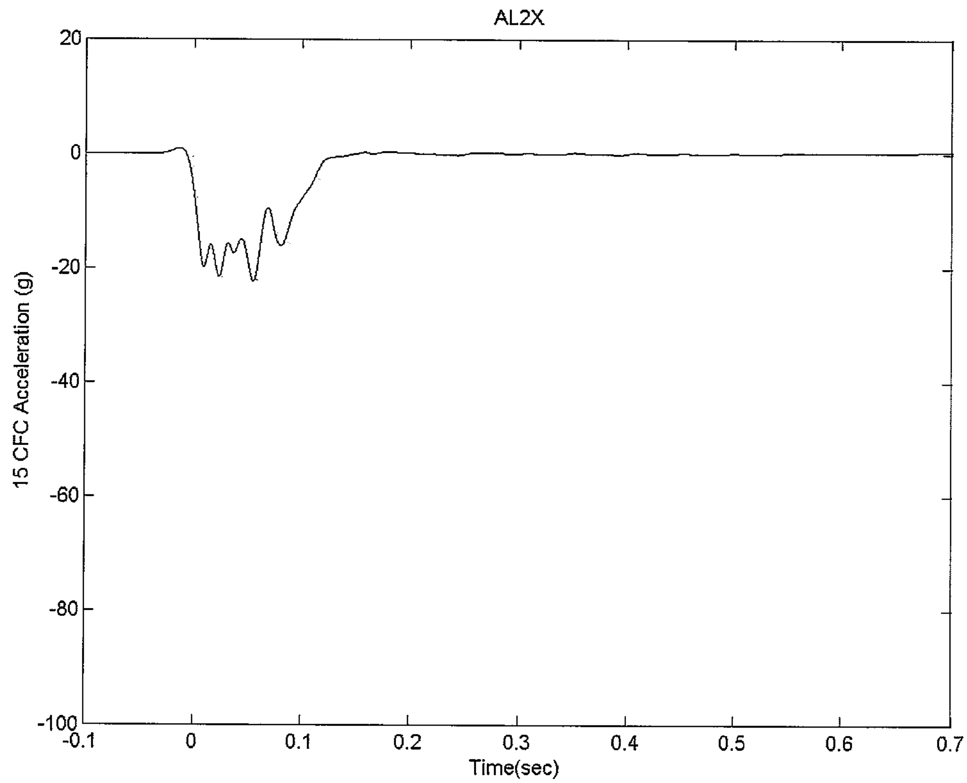
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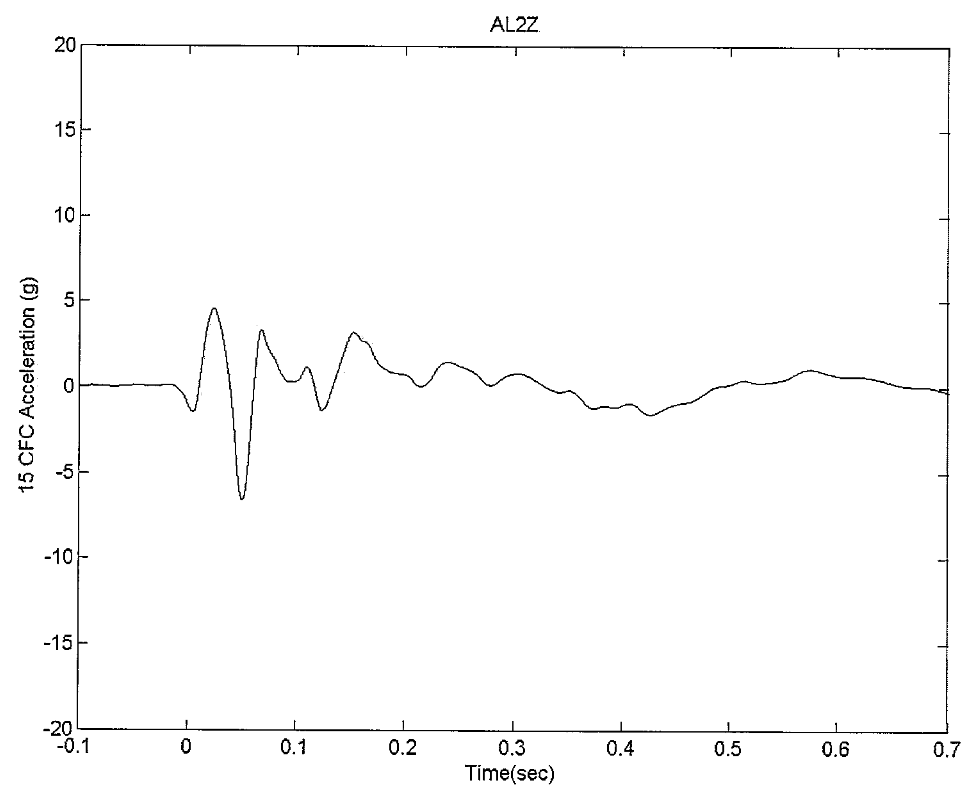
Time(sec)
15 CFC Acceleration (g)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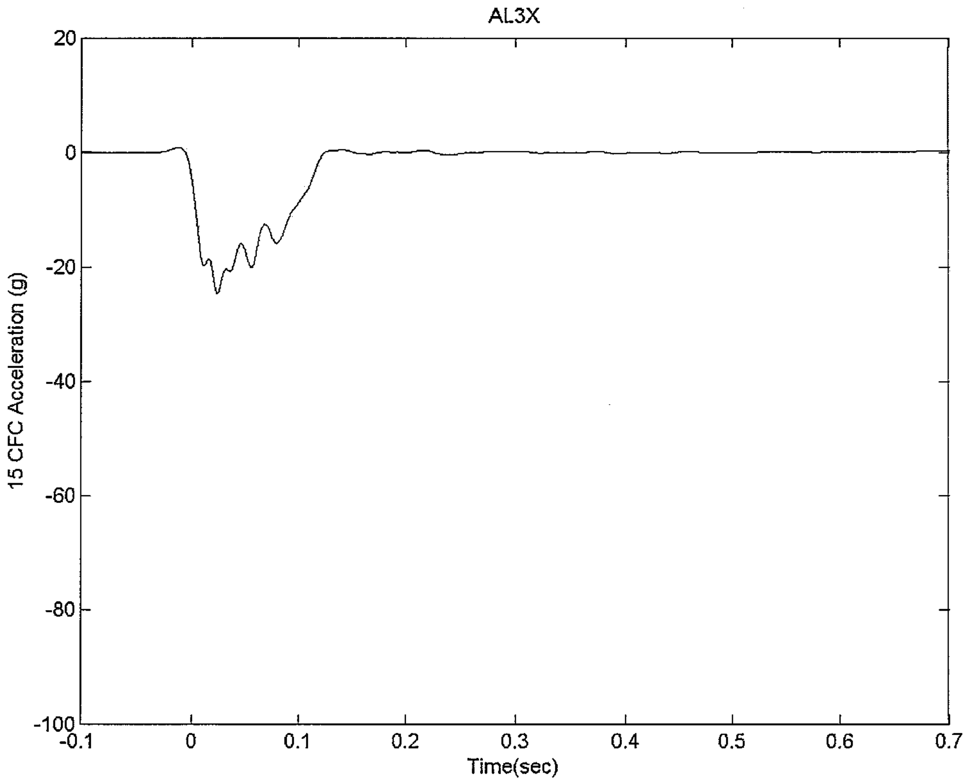
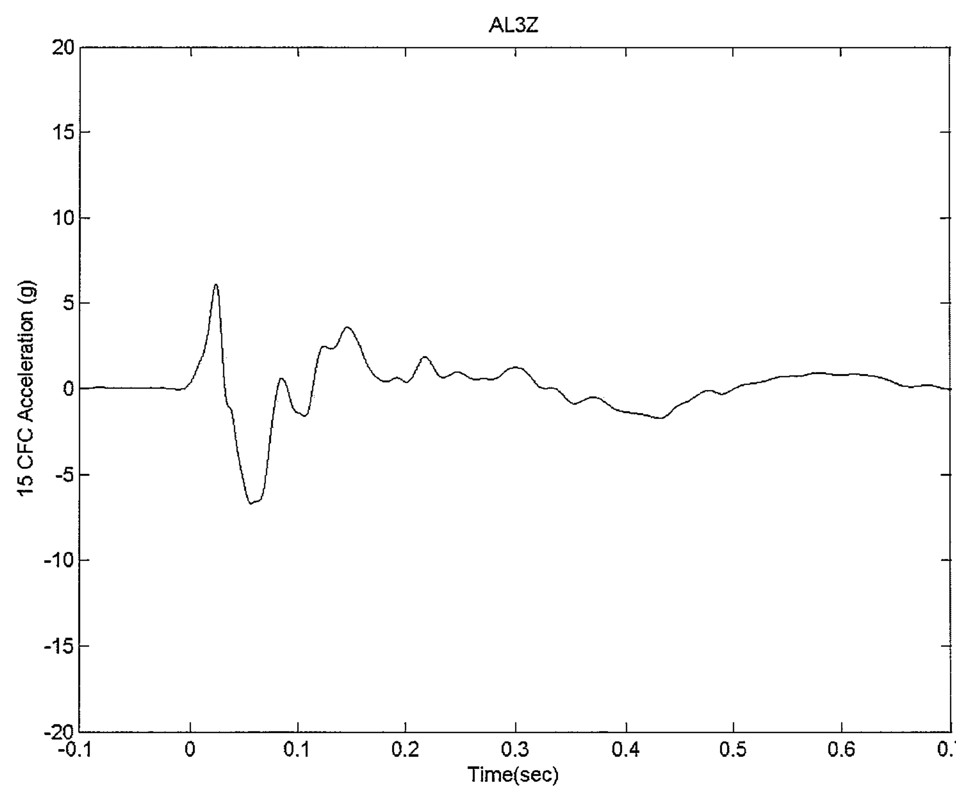
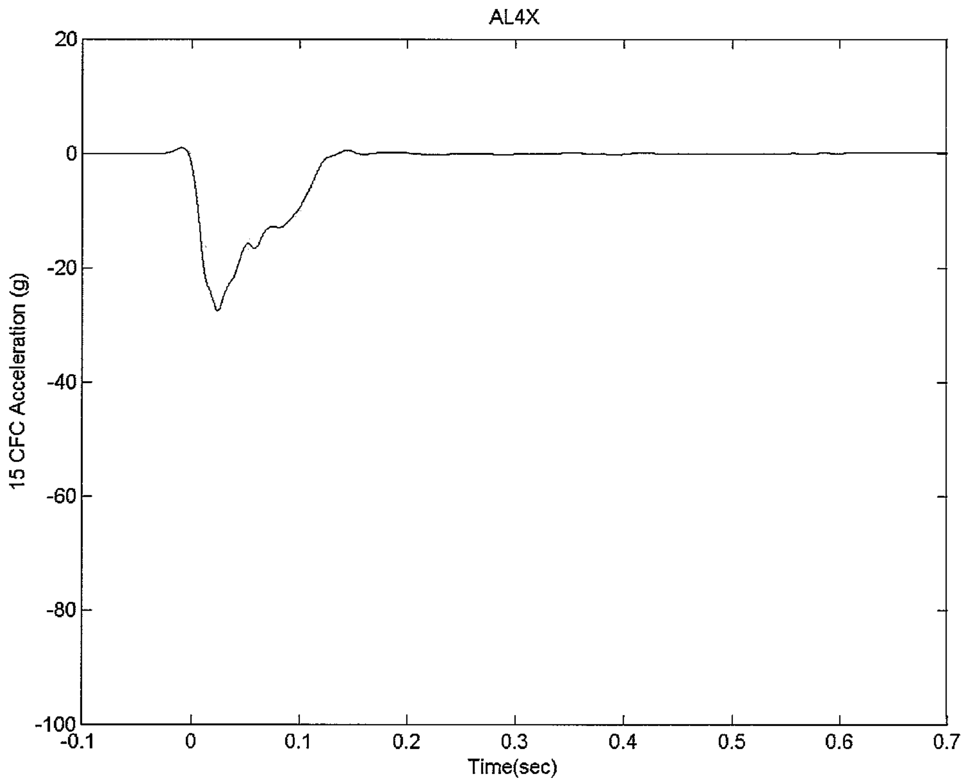
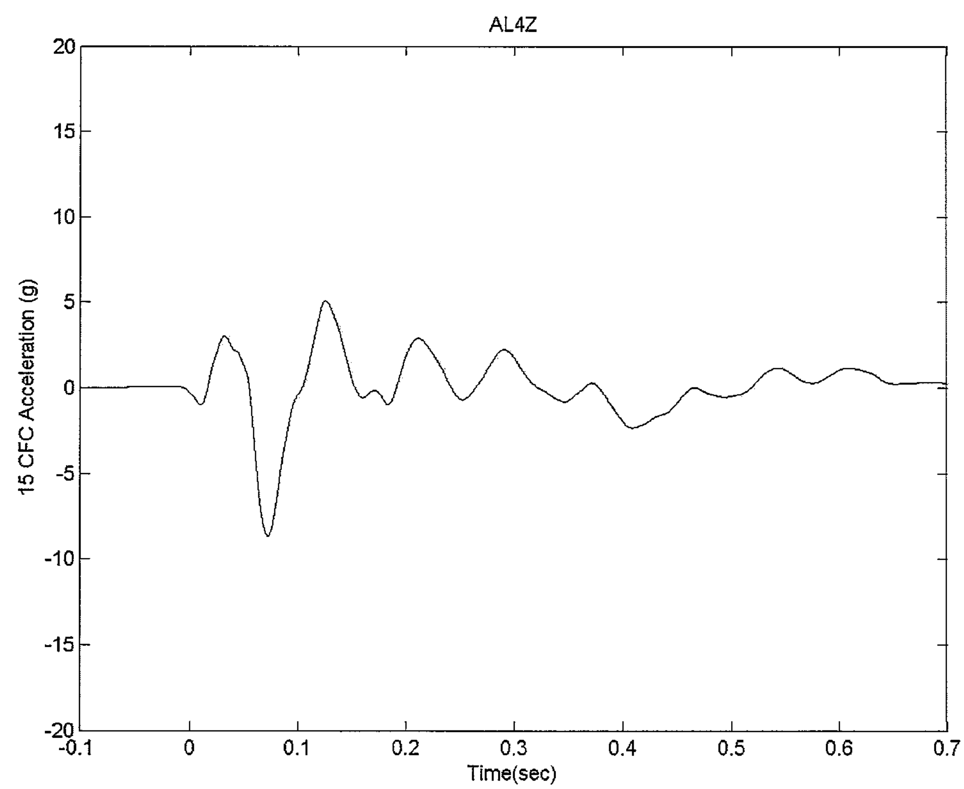
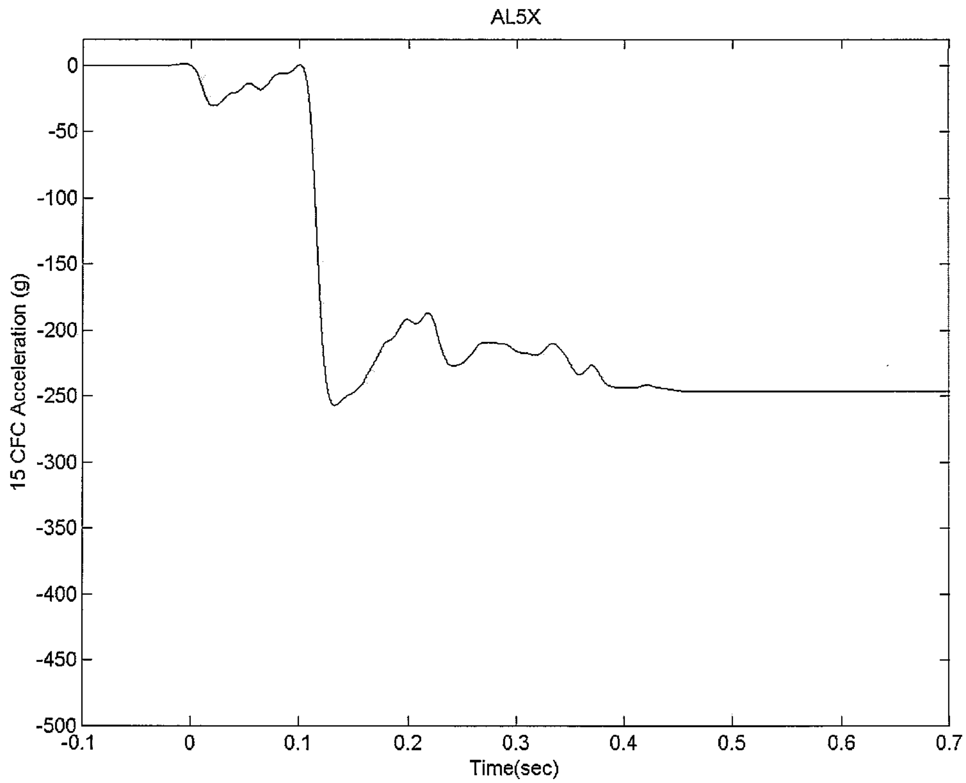
0.5
0.6
0.7
Time(sec)
15 CFC Acceleration (g)

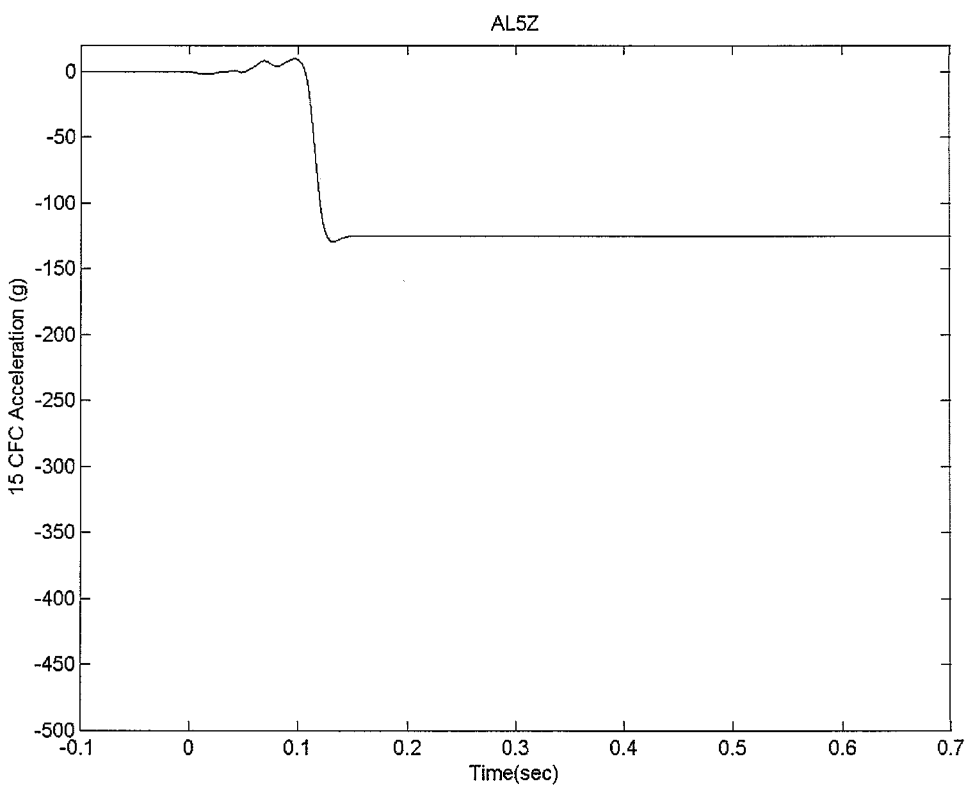

AL3X
15 CFC Acceleration (g)
Time(sec)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

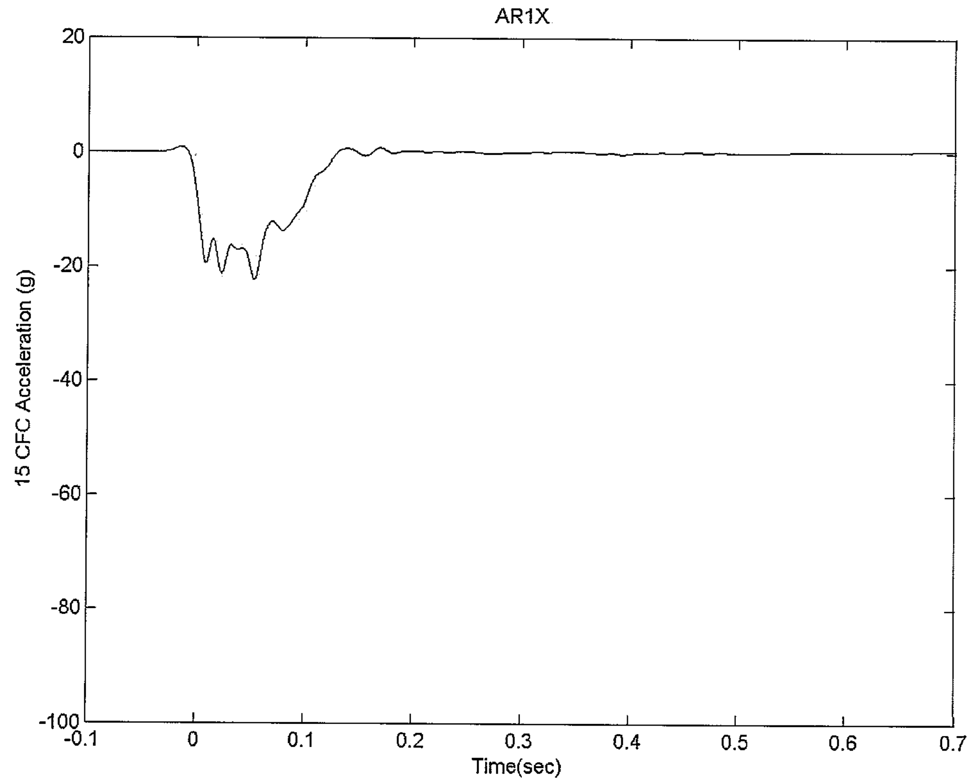

AL3Z
15 CFC Acceleration (g)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

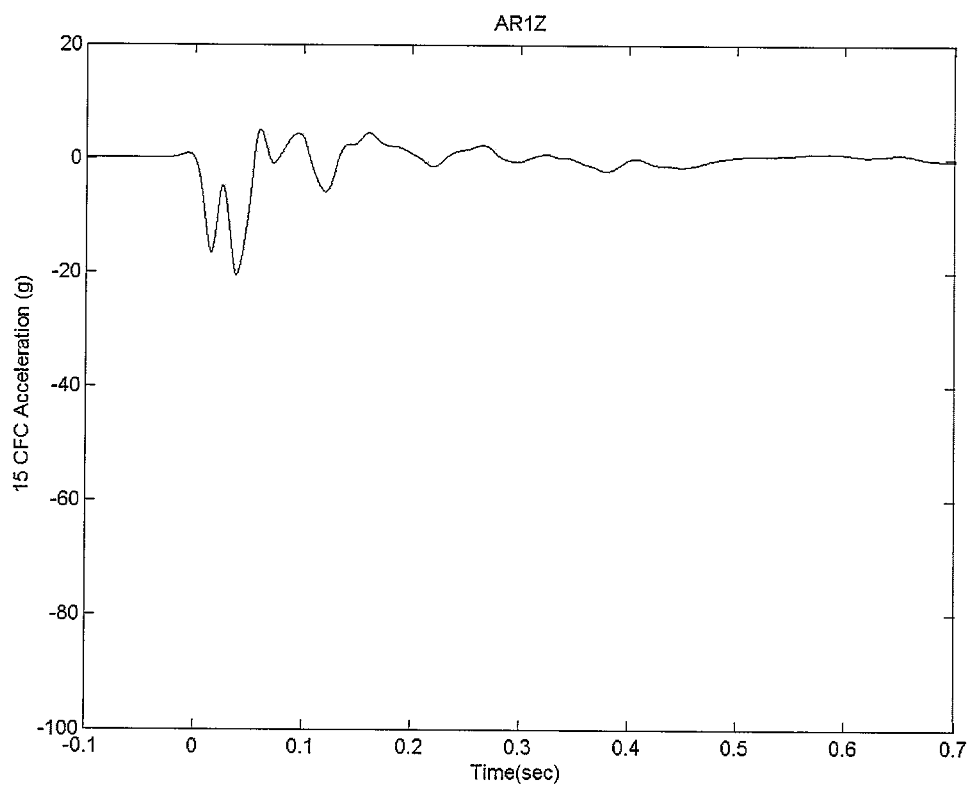

AL4X
15 CFC Acceleration (g)
Time(sec)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

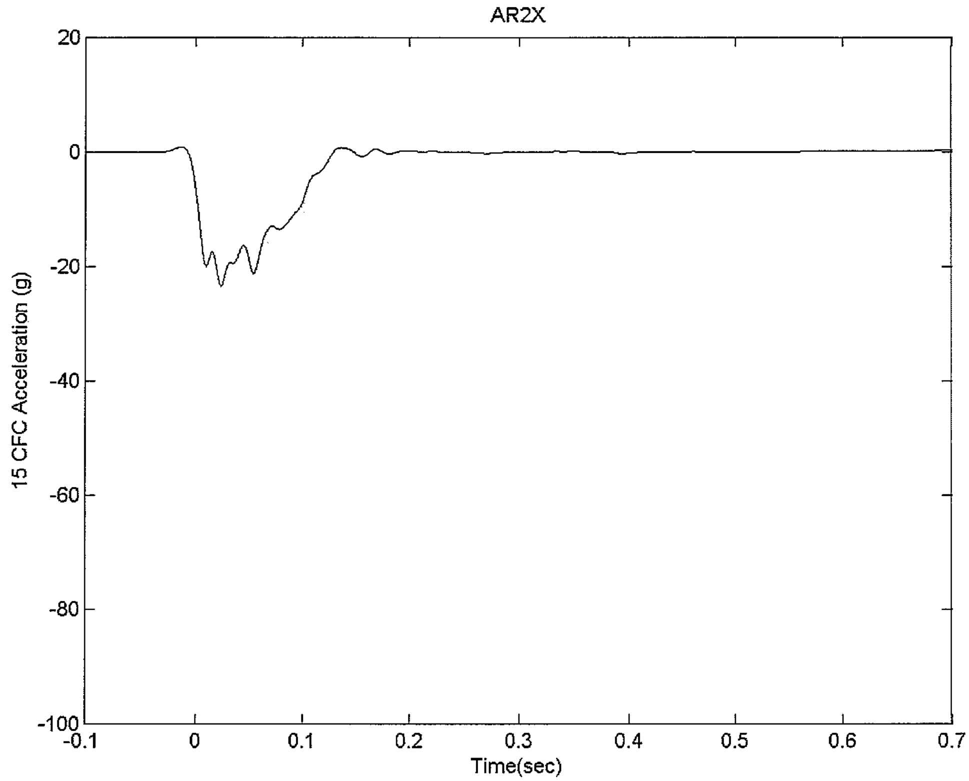

AL4Z
15 CFC Acceleration (g)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


AL5X
15 CFC Acceleration (g)
Time(sec)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

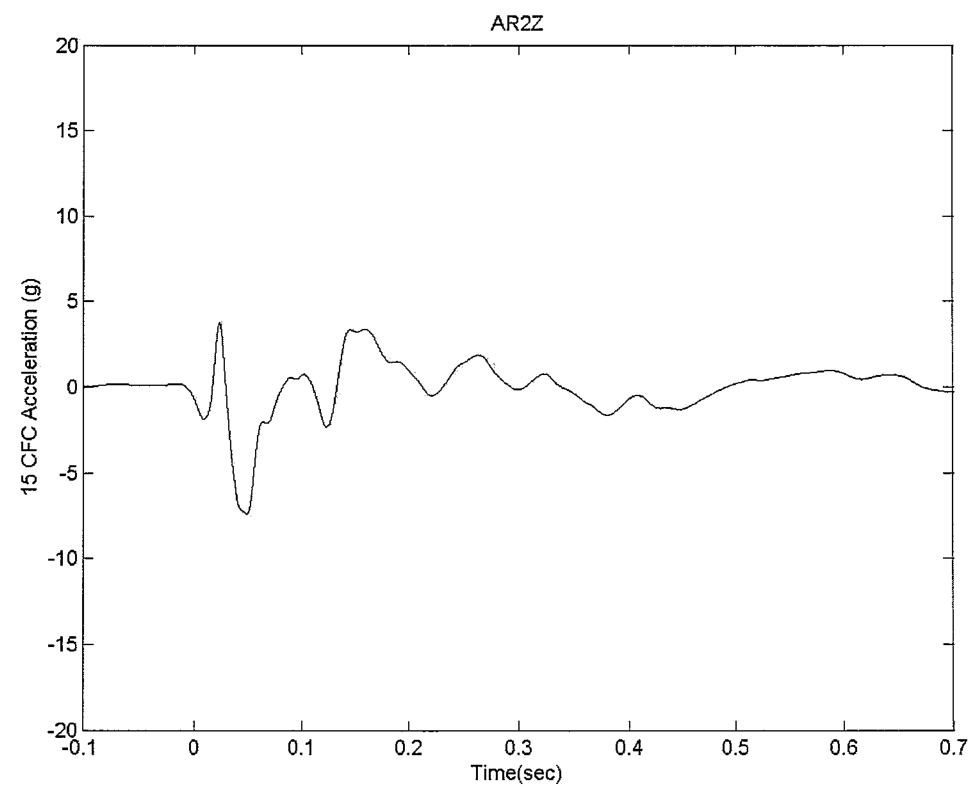

AL5Z
15 CFC Acceleration (g)
Time(sec)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


AR1X
15 CFC Acceleration (g)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

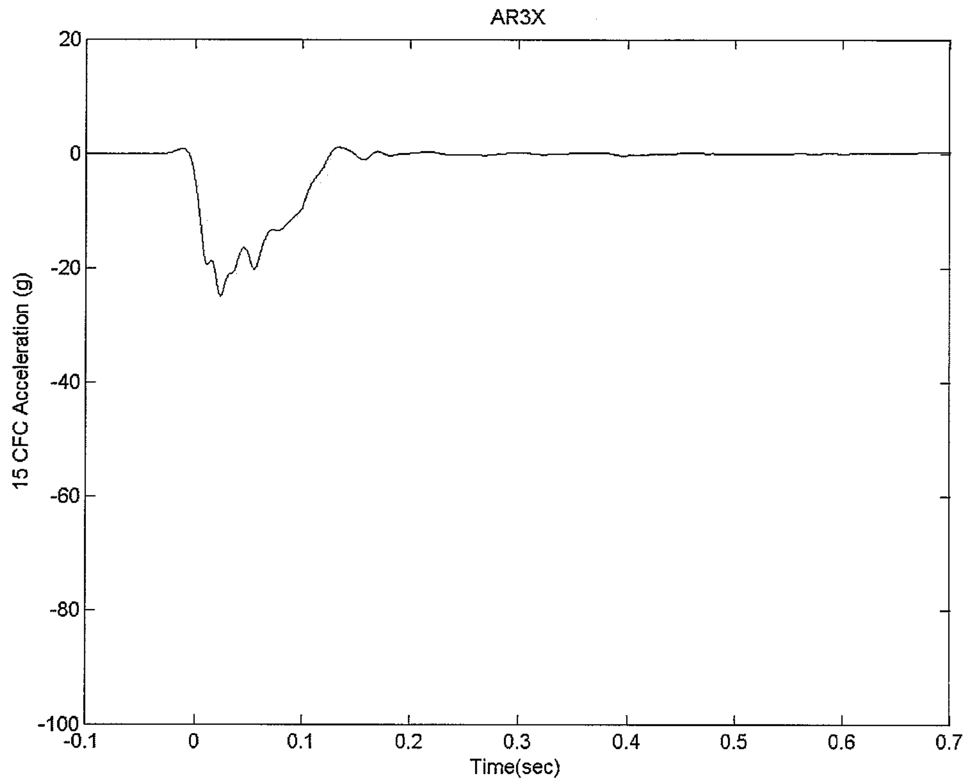

AR1Z
15 CFC Acceleration (g)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

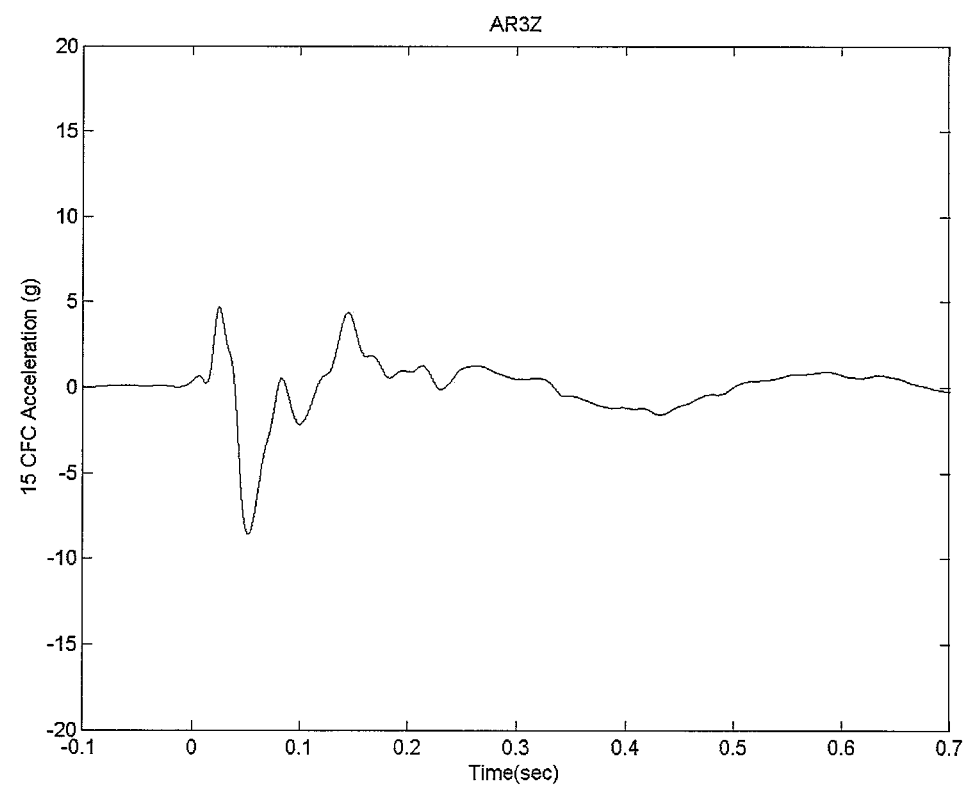


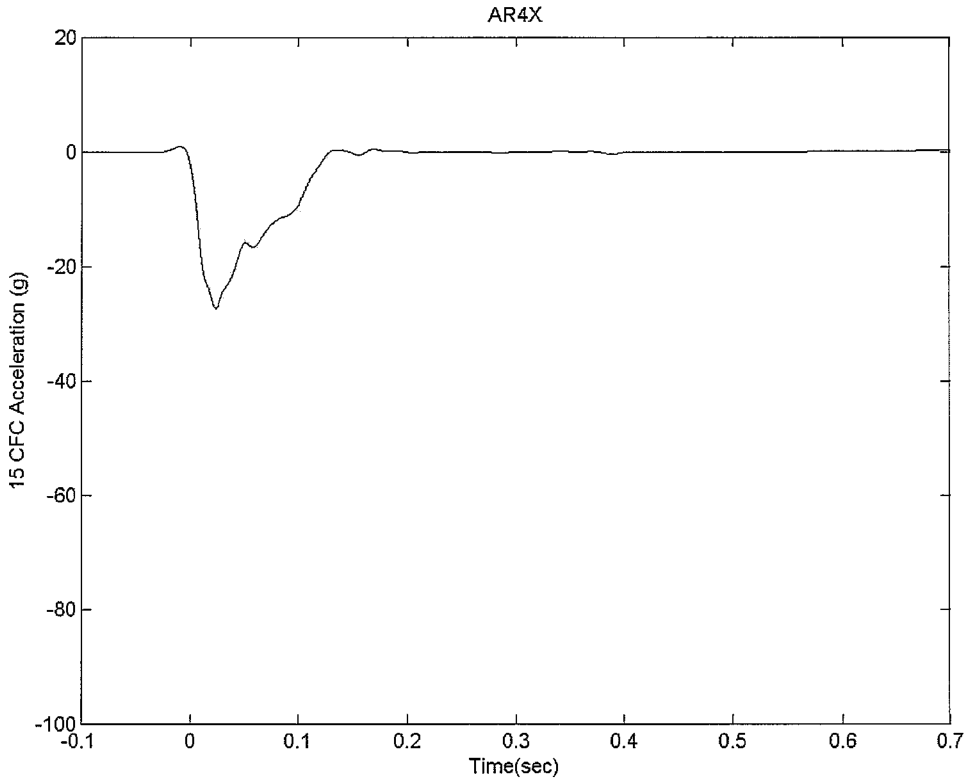
AR2X
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
15 CFC Acceleration (g)

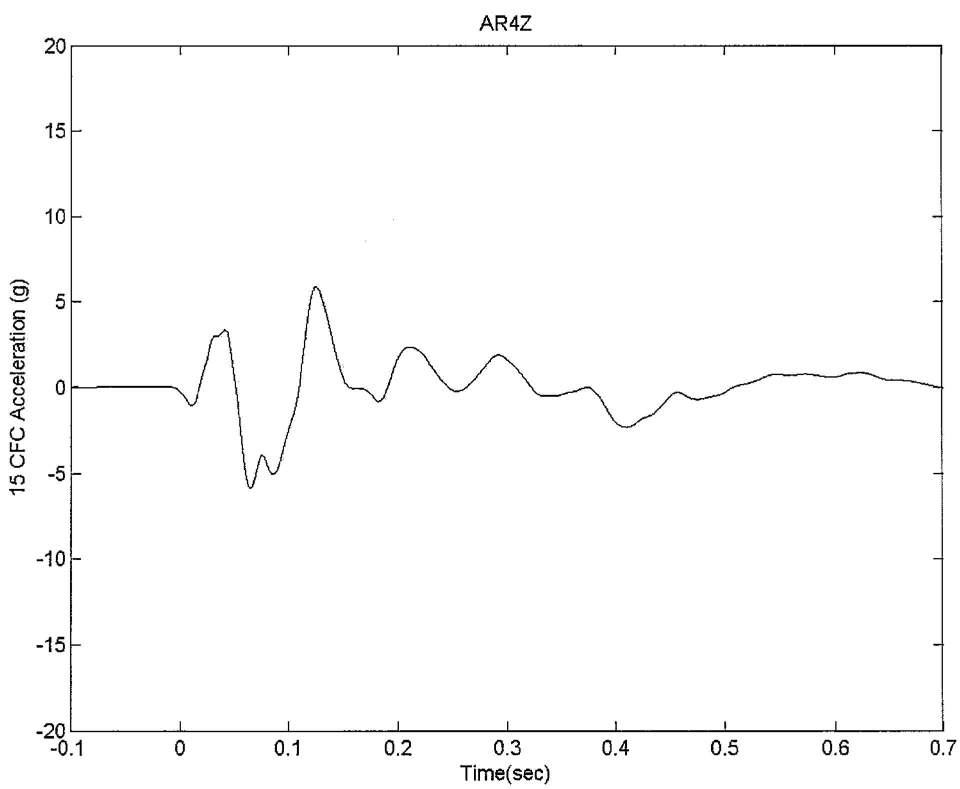


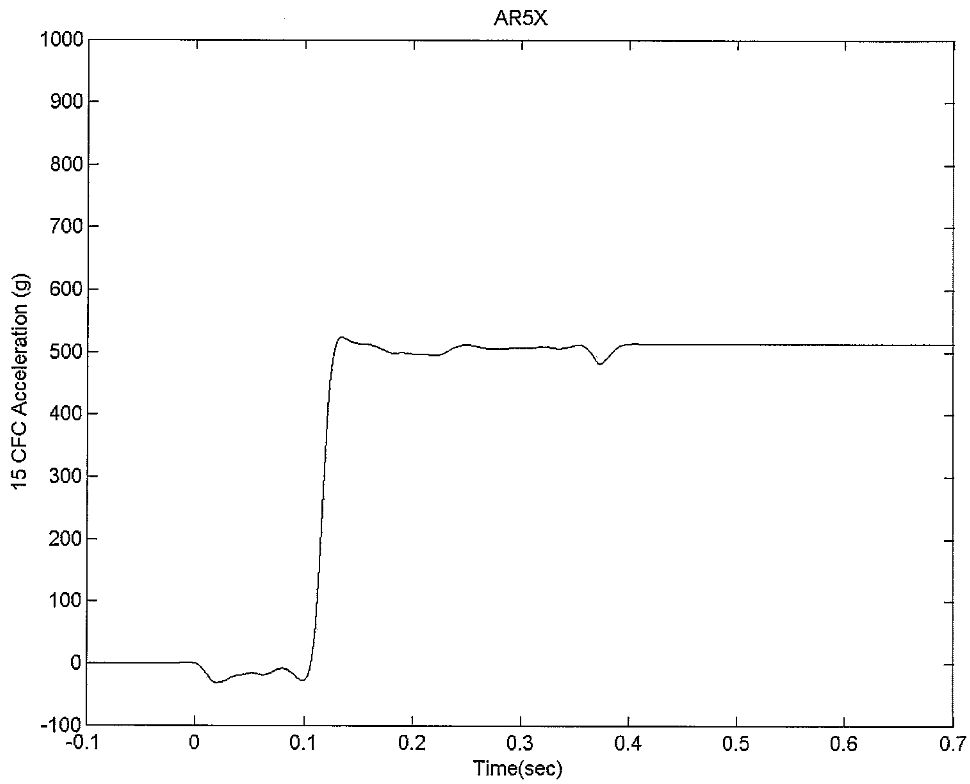
AR2Z
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
15 CFC Acceleration (g)

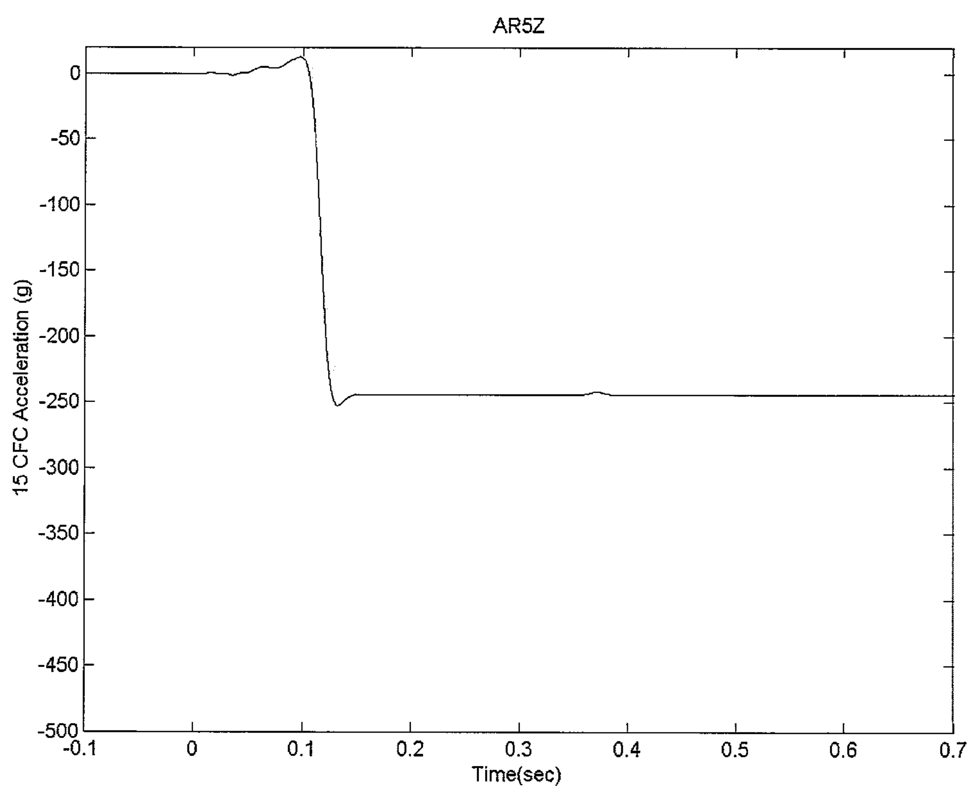

AR3X
20
0
-20
-40
-60
-80
-100
15 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

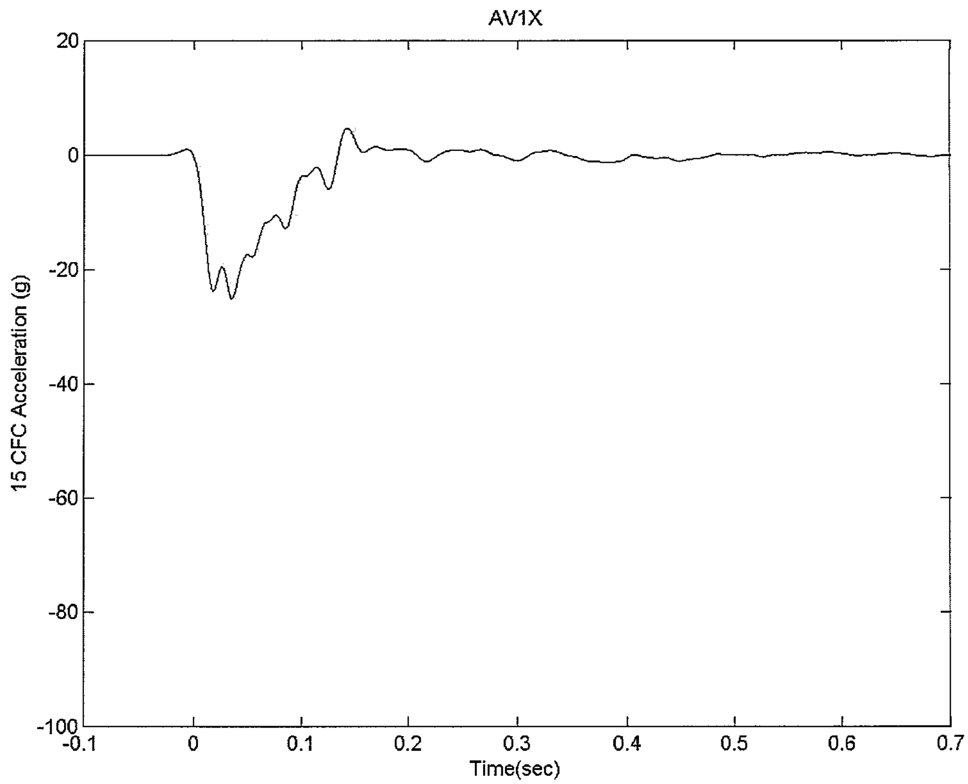

AR3Z
20
15
10
5
0
-5
-10
-15
-20
15 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

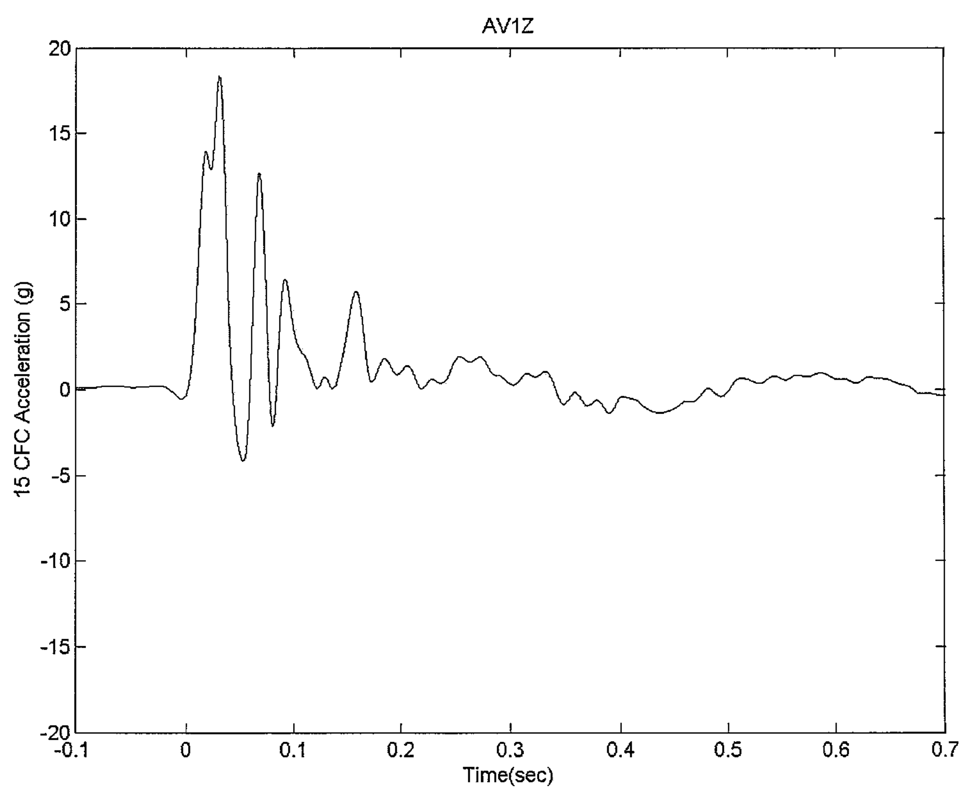

AR4X
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
15 CFC Acceleration (g)

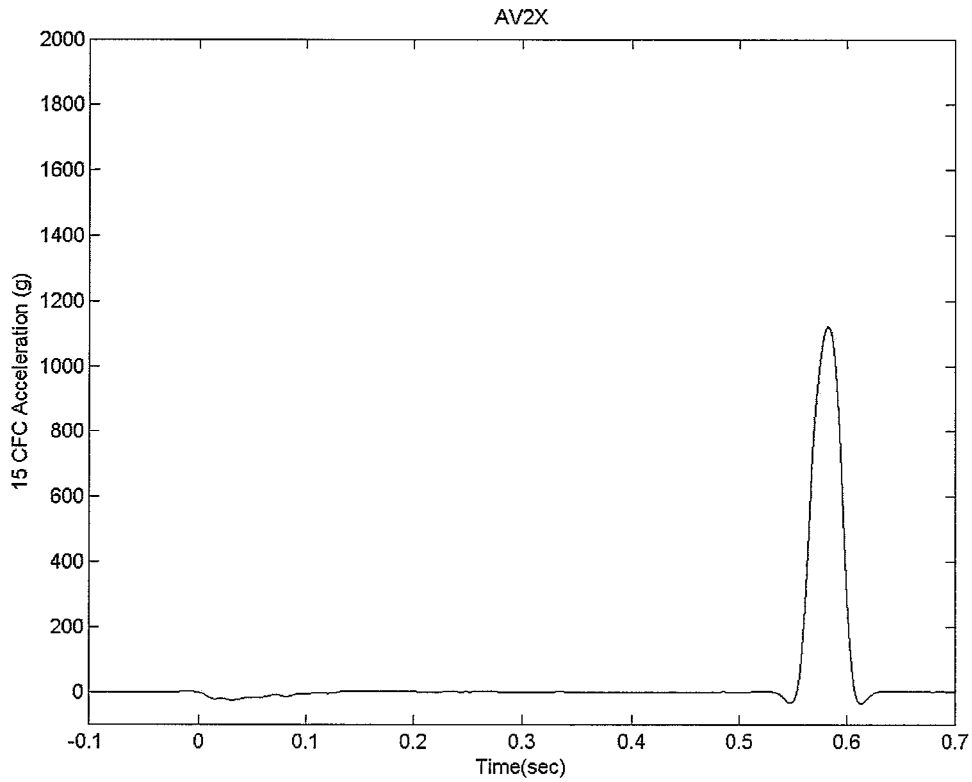

AR4Z
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
15 CFC Acceleration (g)

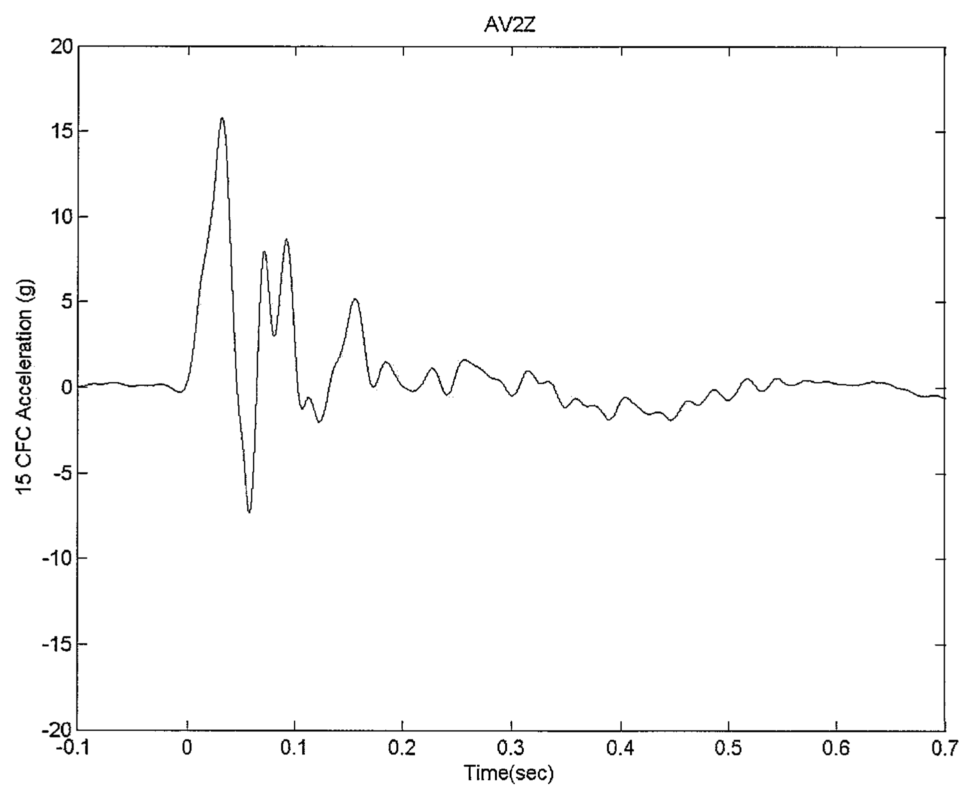

AR5X
15 CFC Acceleration (g)
Time(sec)
1000
900
800
700
600
500
400
300
200
100
0
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

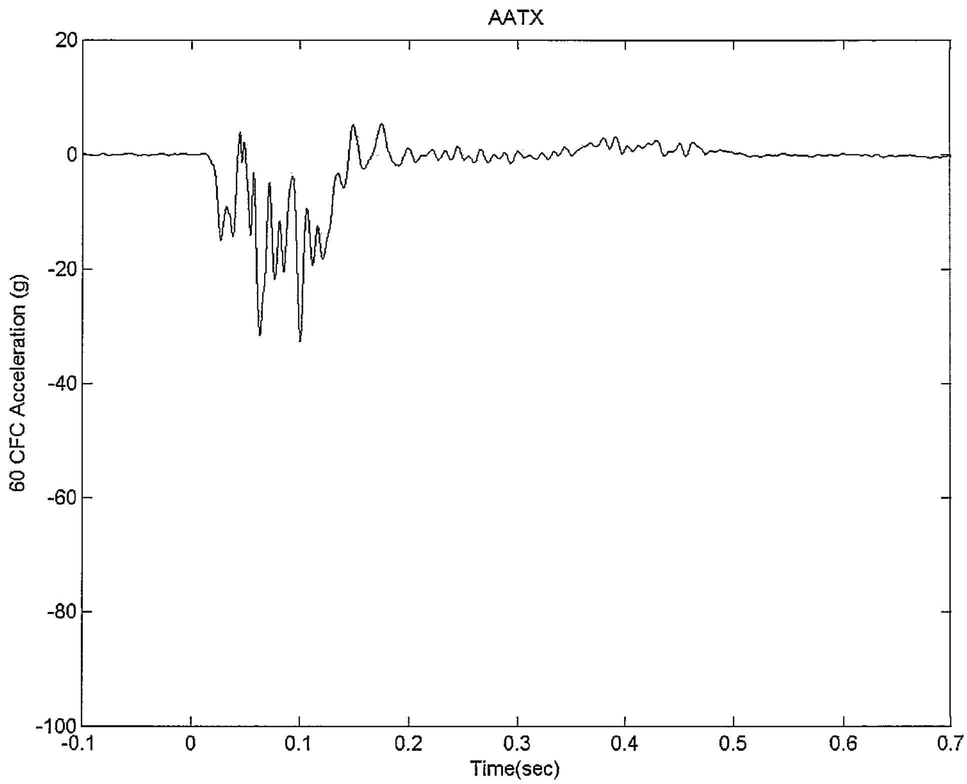

AR5Z
15 CFC Acceleration (g)
Time(sec)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

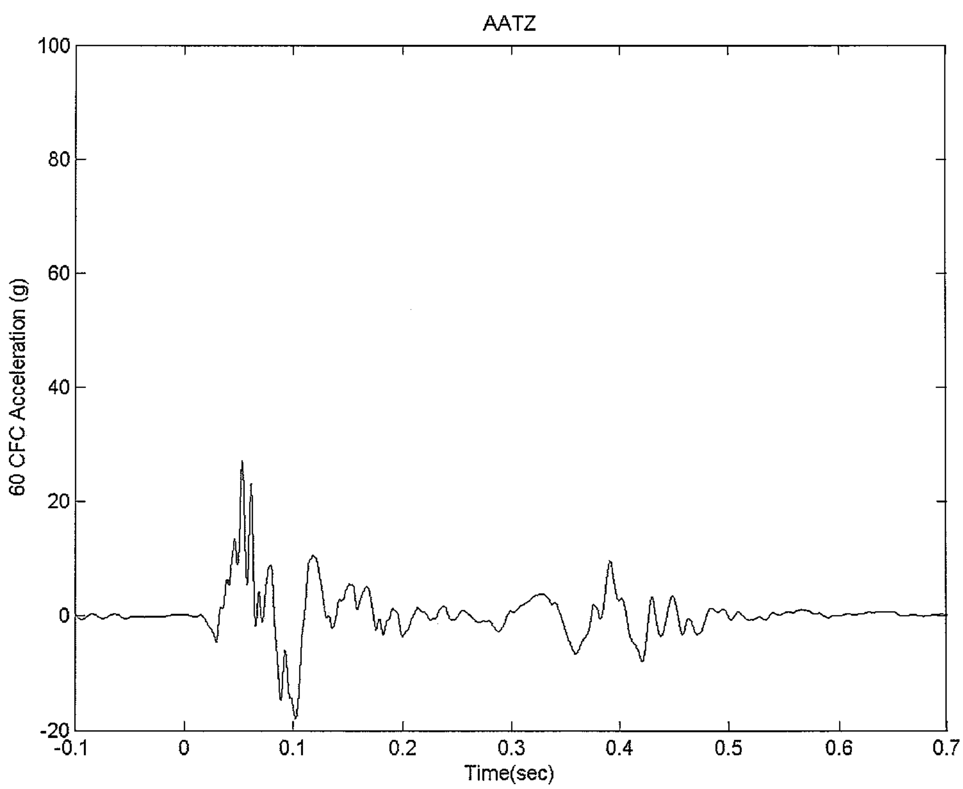

AV1X
15 CFC Acceleration (g)
Time(sec)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

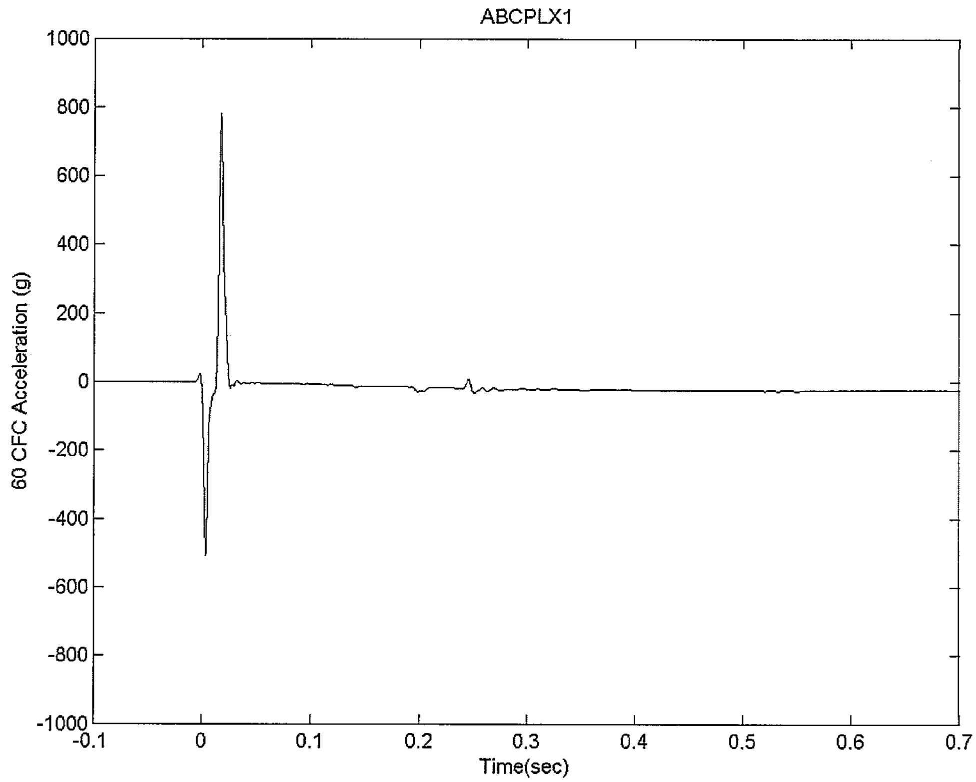

AV1Z
15 CFC Acceleration (g)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

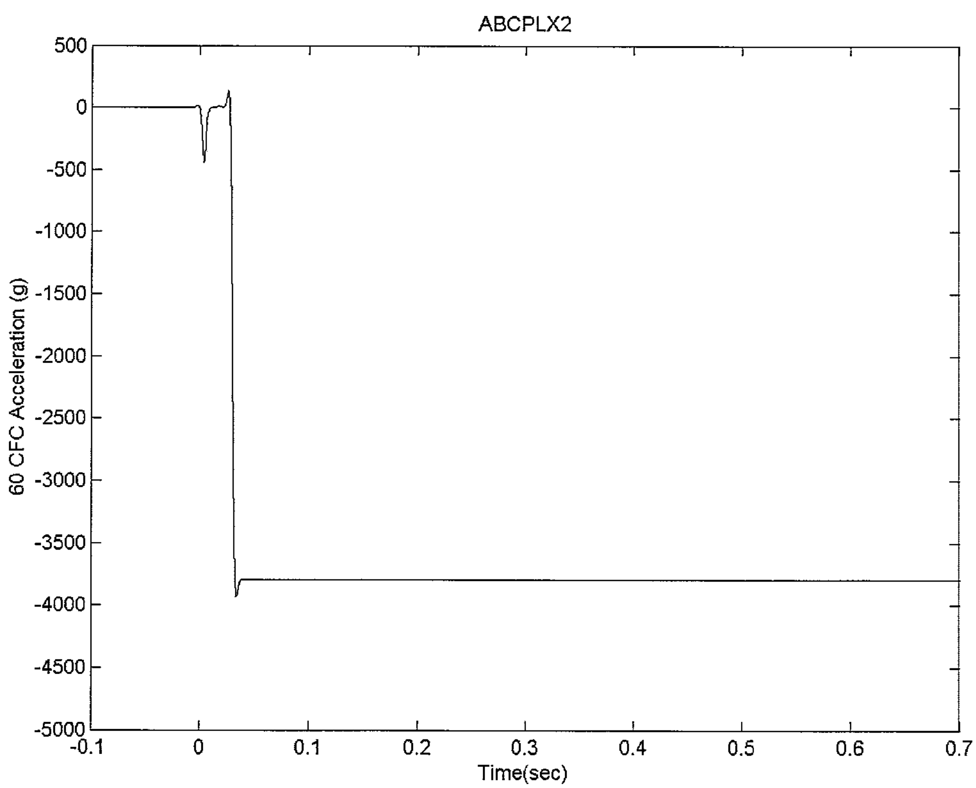

AV2X
15 CFC Acceleration (g)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

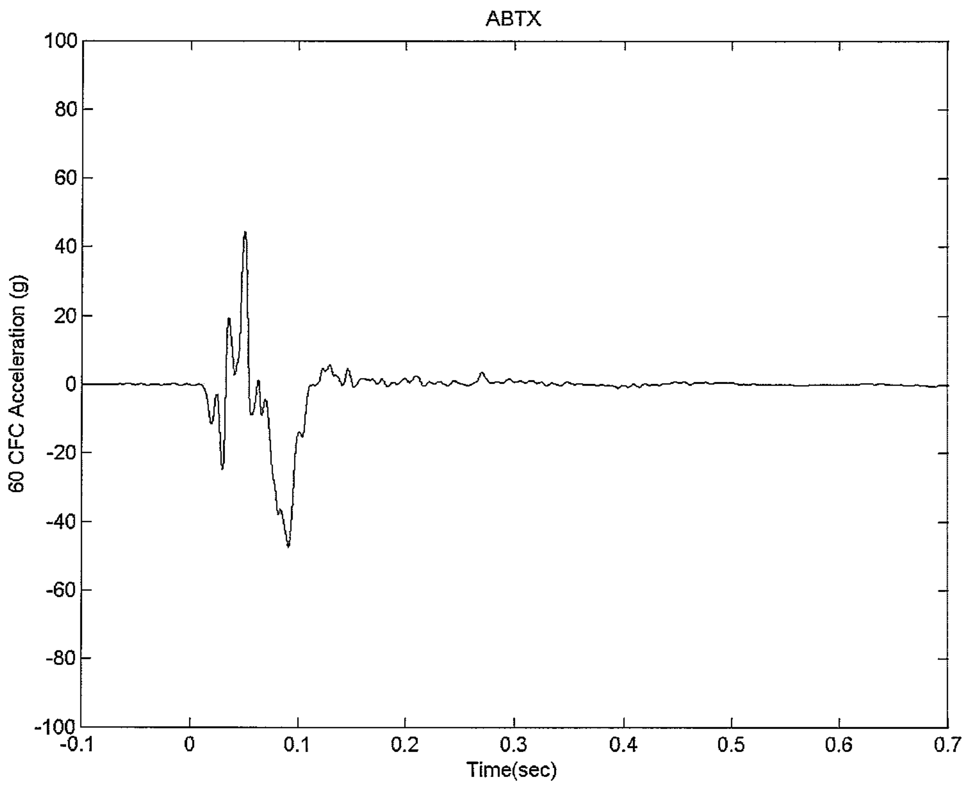

AV2Z
15 CFC Acceleration (g)
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

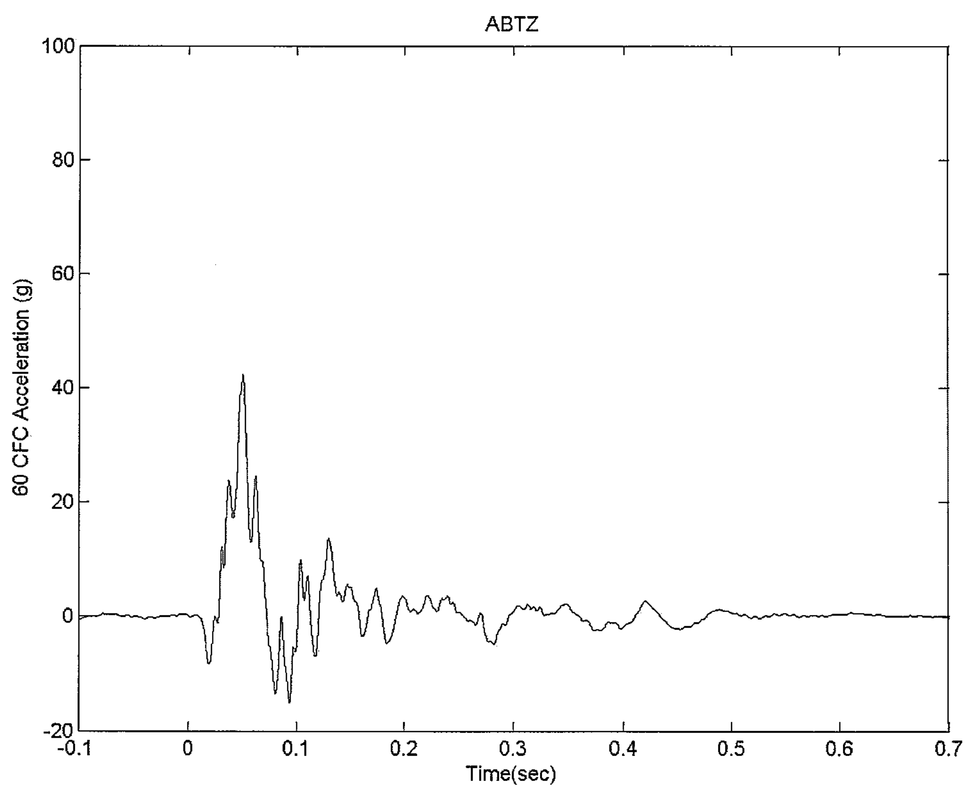

AATX
60 CFC Acceleration (g)
Time(sec)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

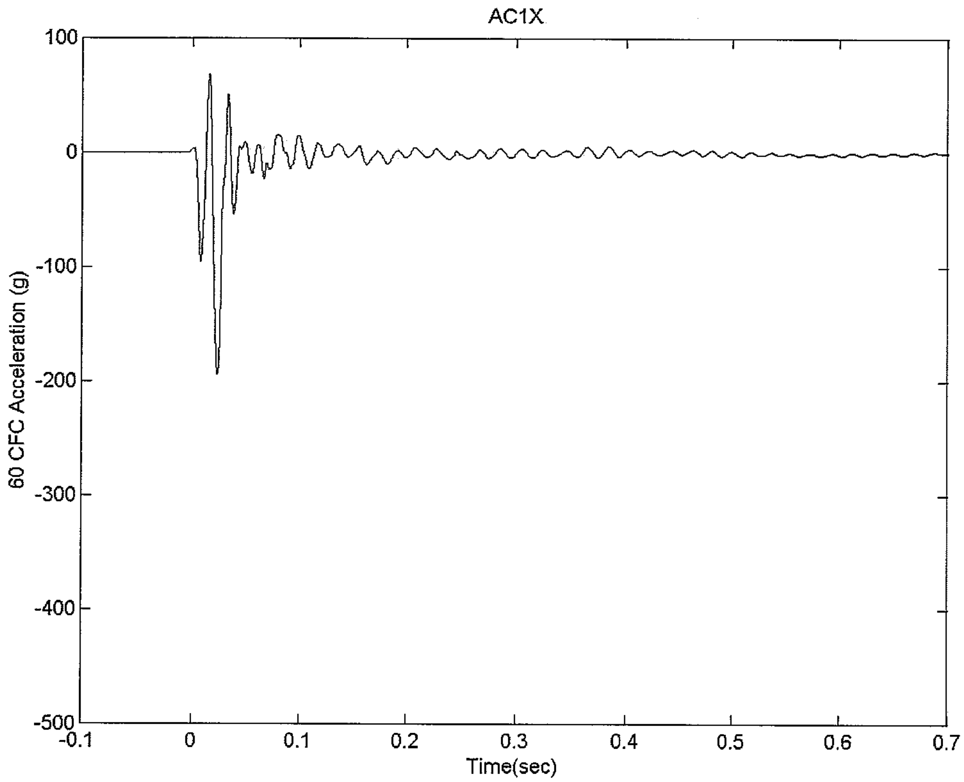

AATZ
60 CFC Acceleration (g)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

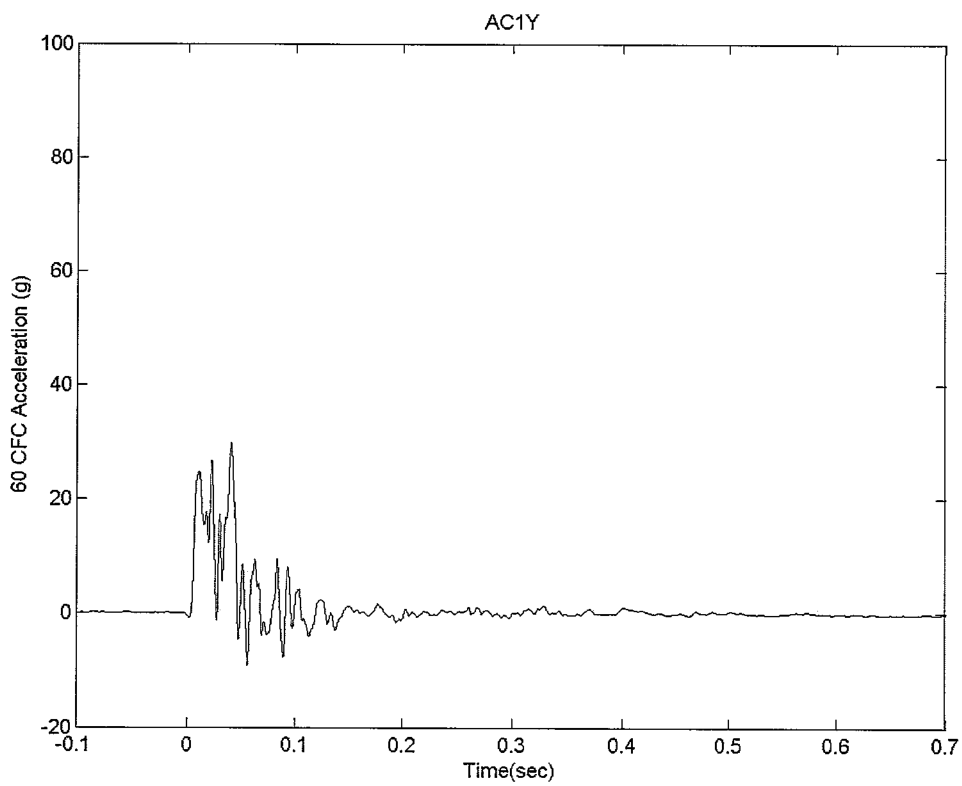

ABCPLX1
60 CFC Acceleration (g)
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

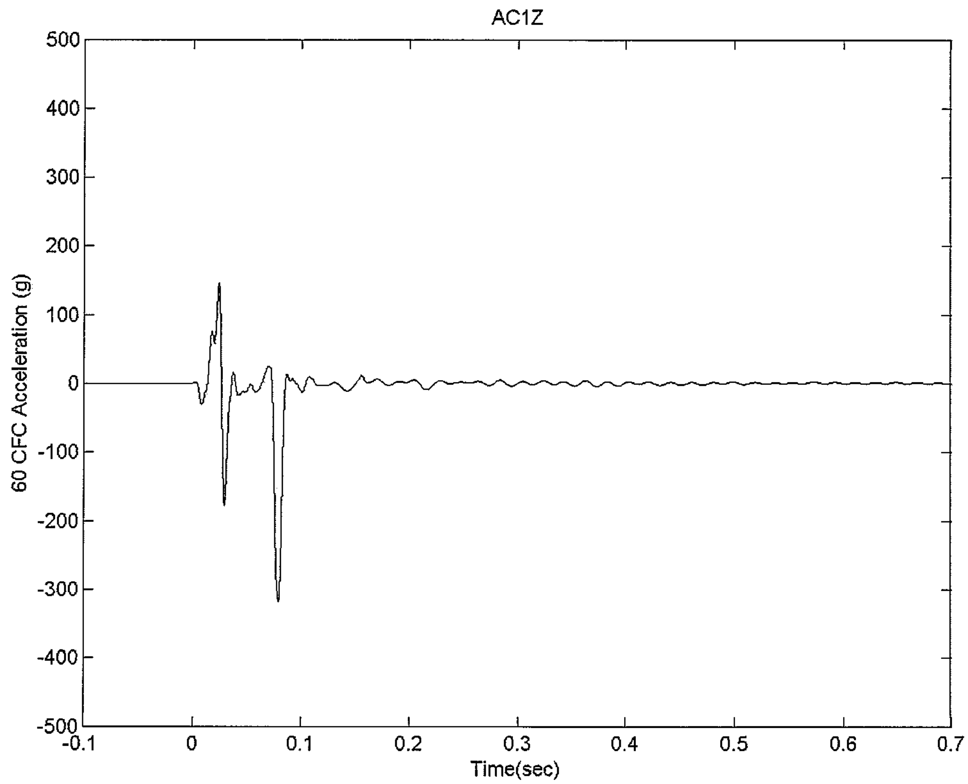

ABCPLX2
60 CFC Acceleration (g)
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

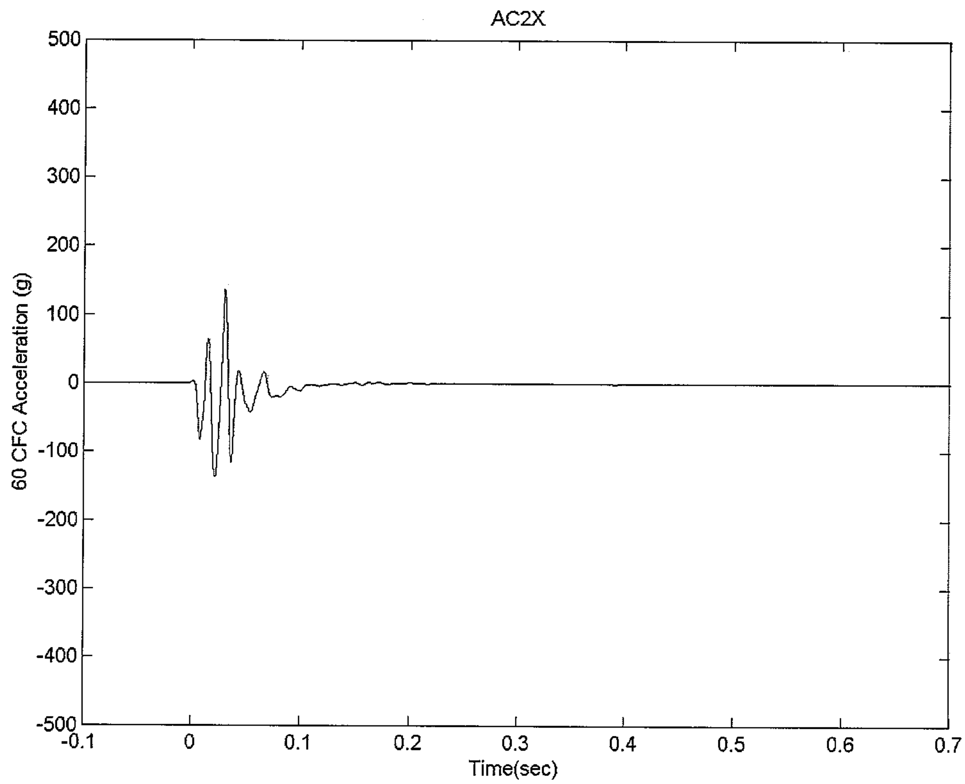

ABTX
60 CFC Acceleration (g)
Time(sec)

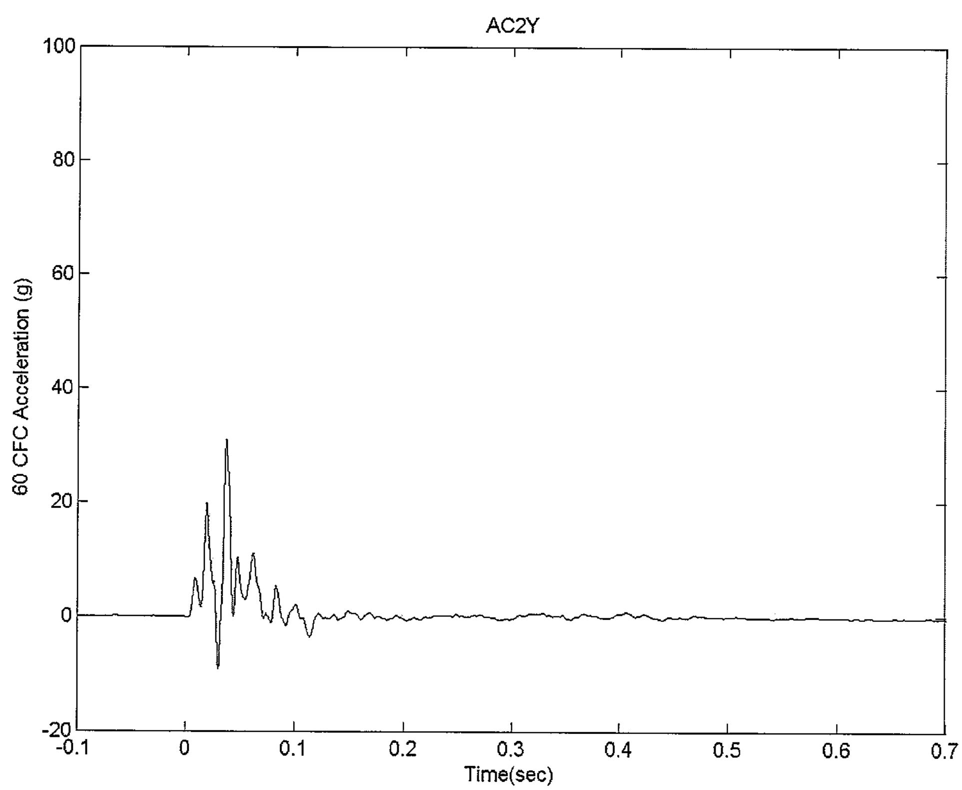

ABTZ
60 CFC Acceleration (g)
Time(sec)

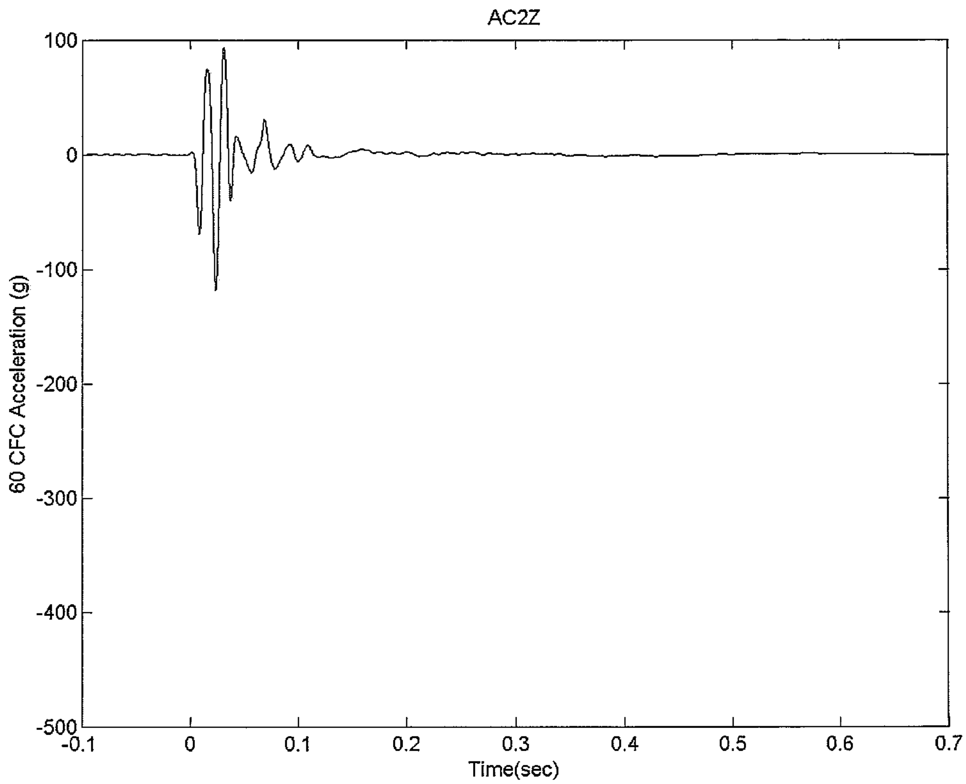

AC1X
60 CFC Acceleration (g)
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AC1Y
60 CFC Acceleration (g)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

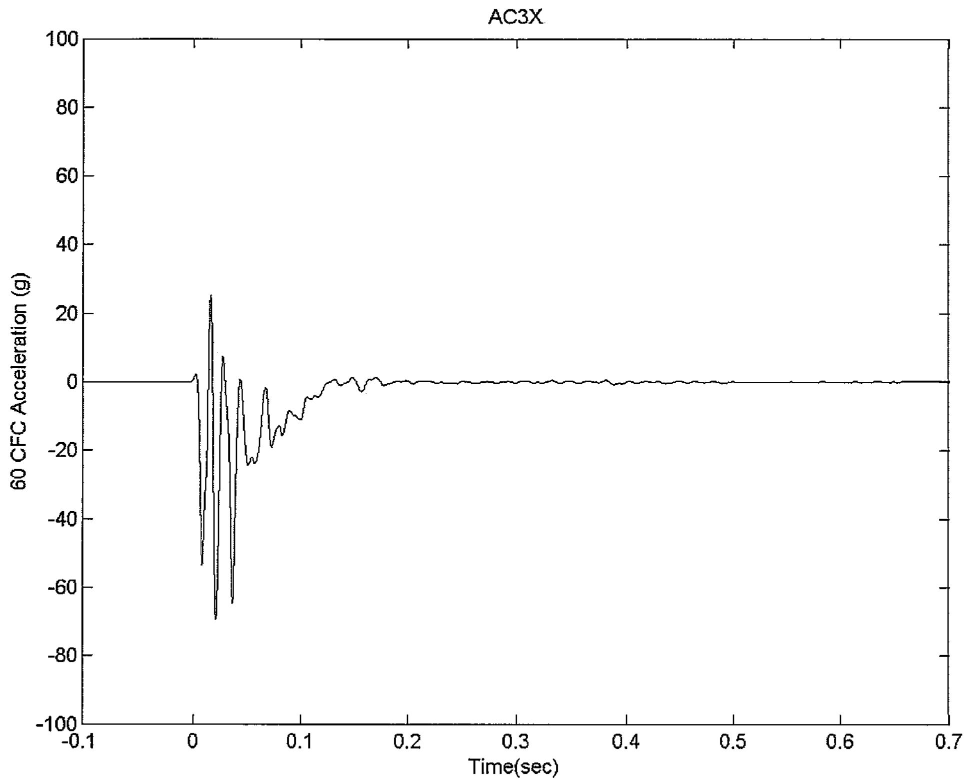

AC1Z
500
400
300
200
100
0
-100
-200
-300
-400
-500
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

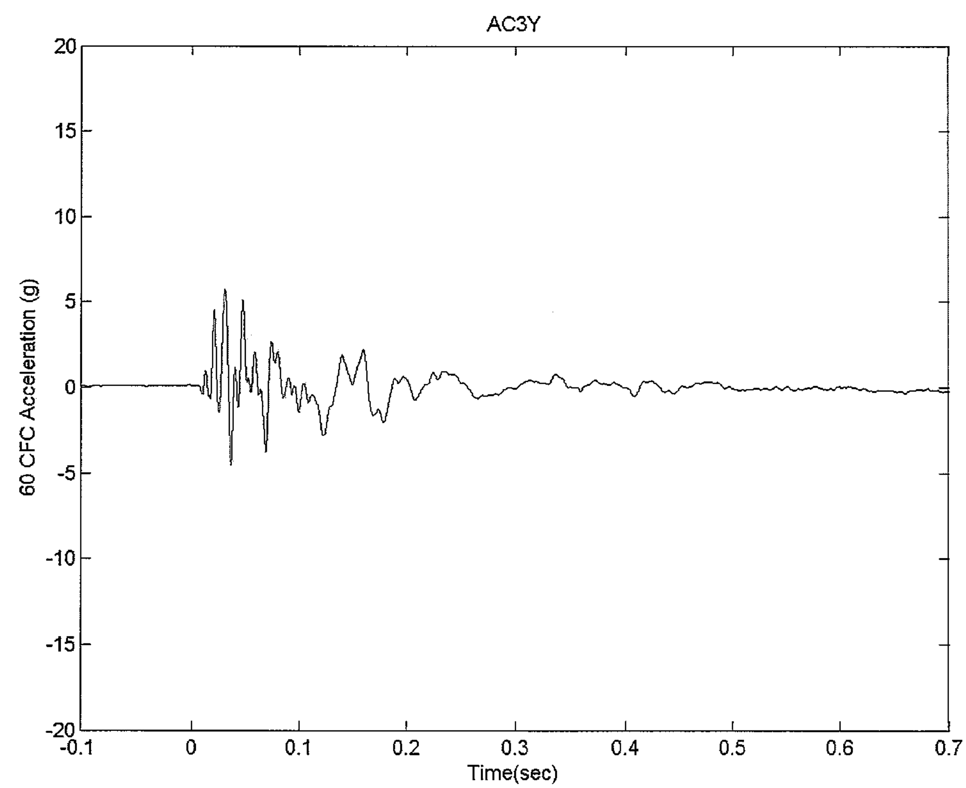

AC2X
500
400
300
200
100
0
-100
-200
-300
-400
-500
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

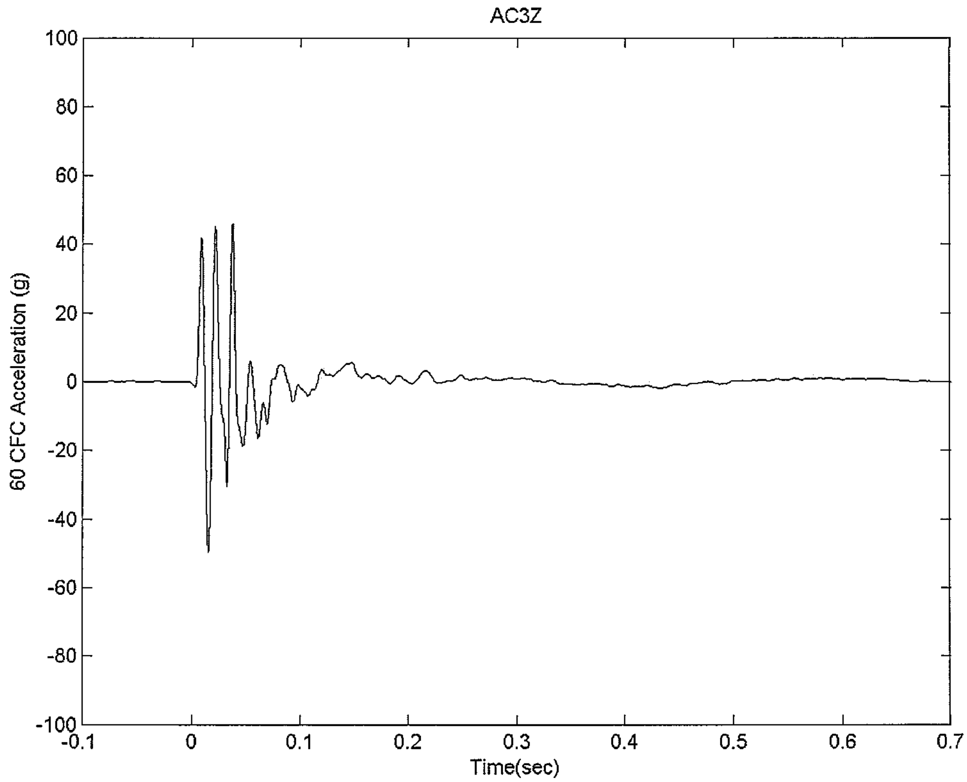

AC2Y
100
80
60
40
20
0
-20
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

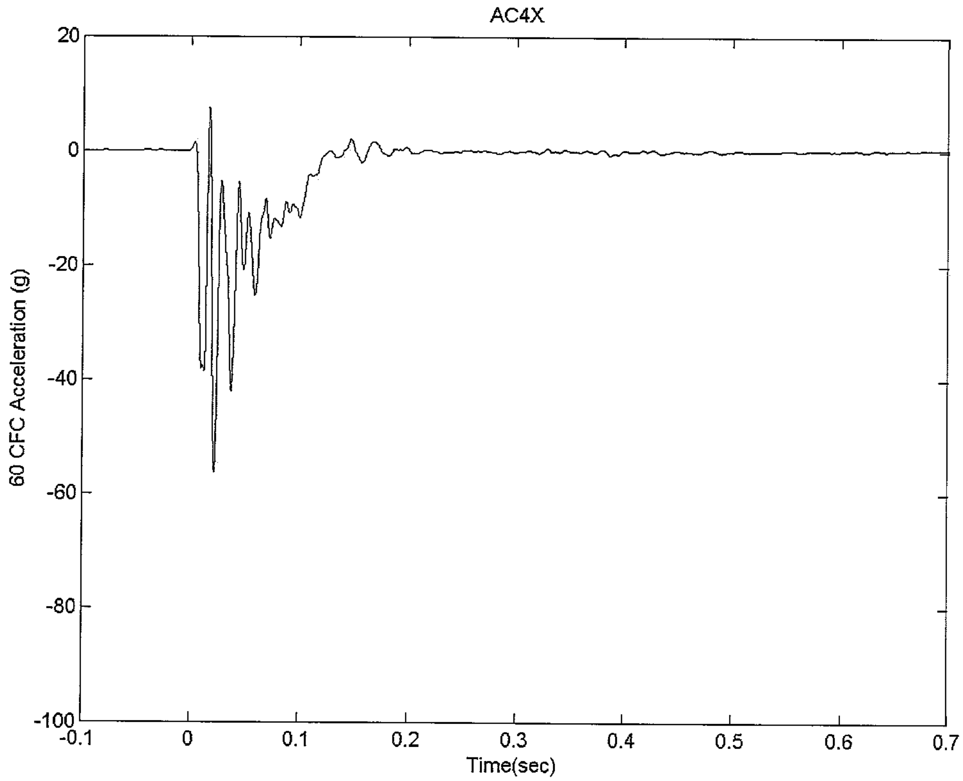


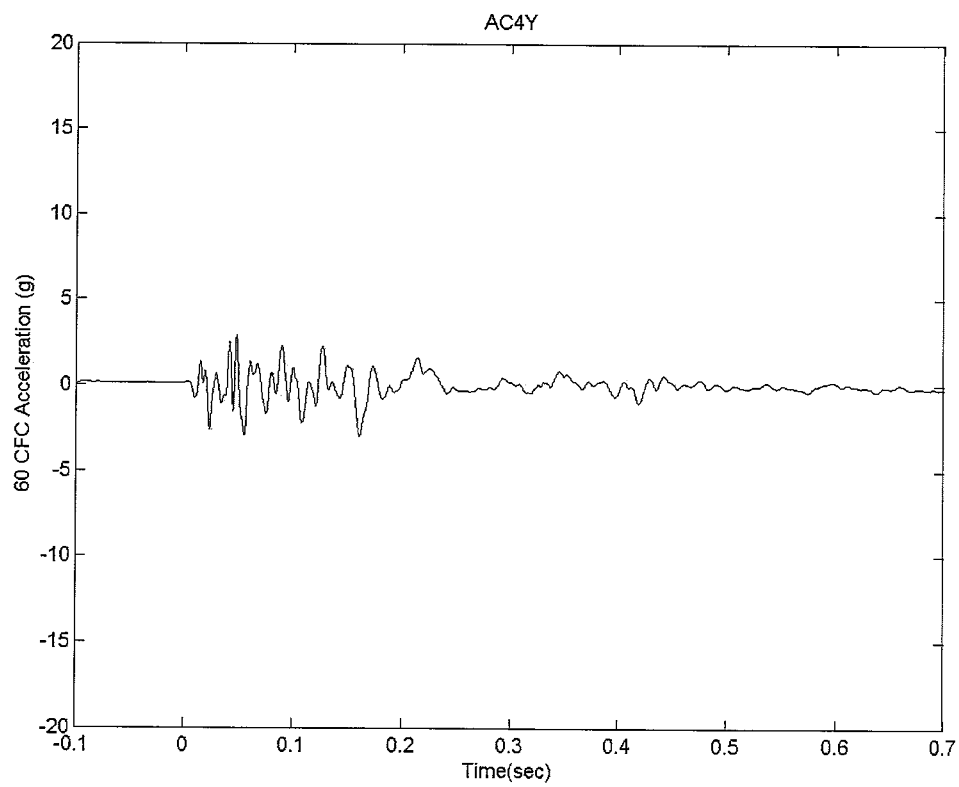
AC2Z
100
0
-100
-200
-300
-400
-500
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

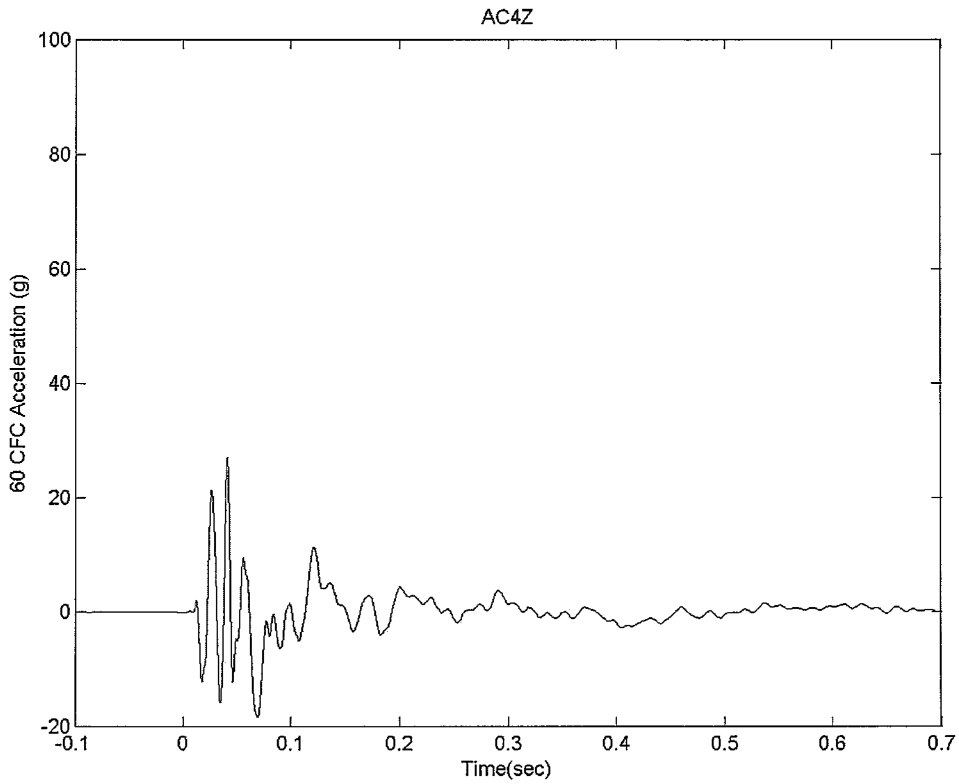

AC3X
60 CFC Acceleration (g)
Time(sec)


AC3Y
60 CFC Acceleration (g)
Time(sec)

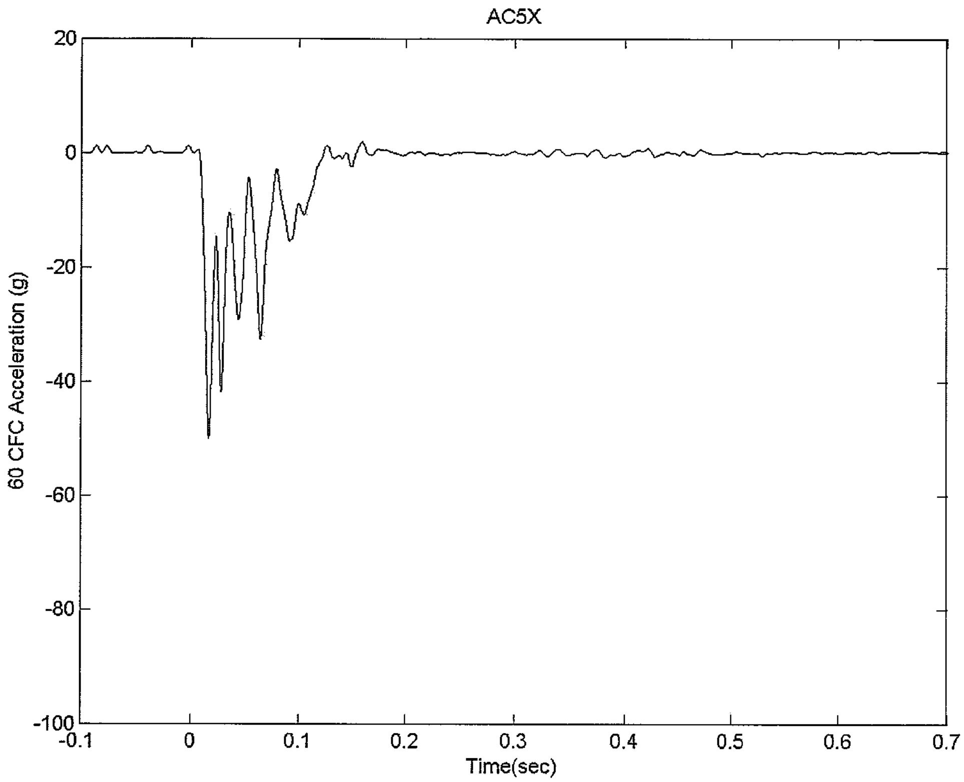

AC3Z
100
80
60
40
20
0
-20
-40
-60
-80
-100
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

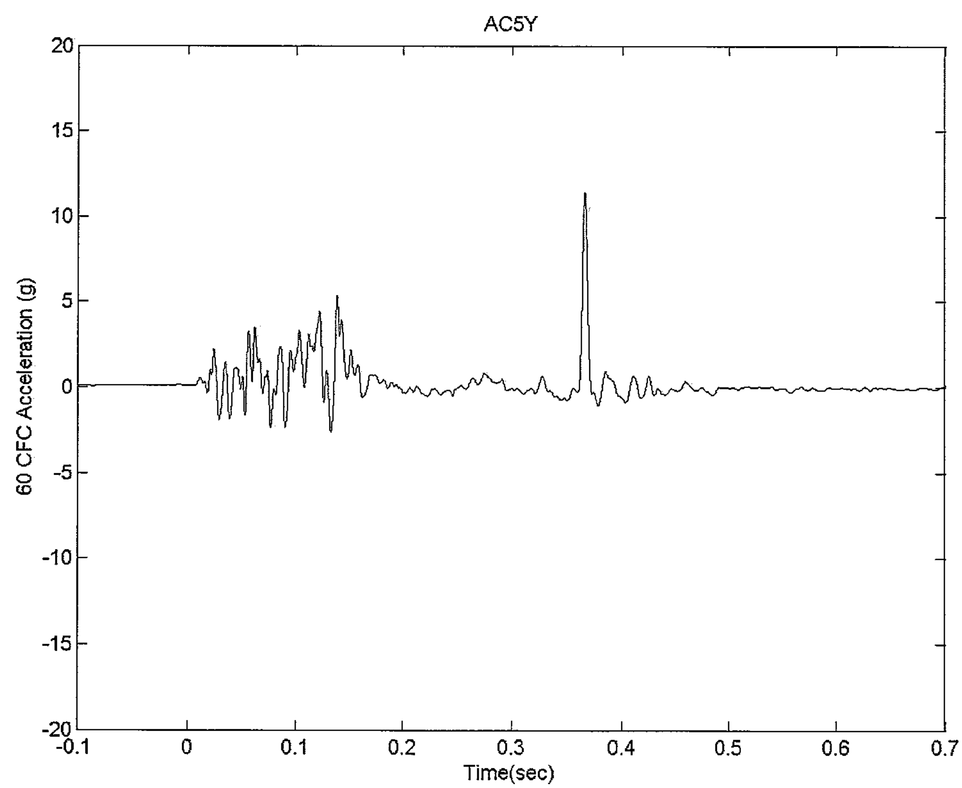

AC4X
20
0
-20
-40
-60
-80
-100
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

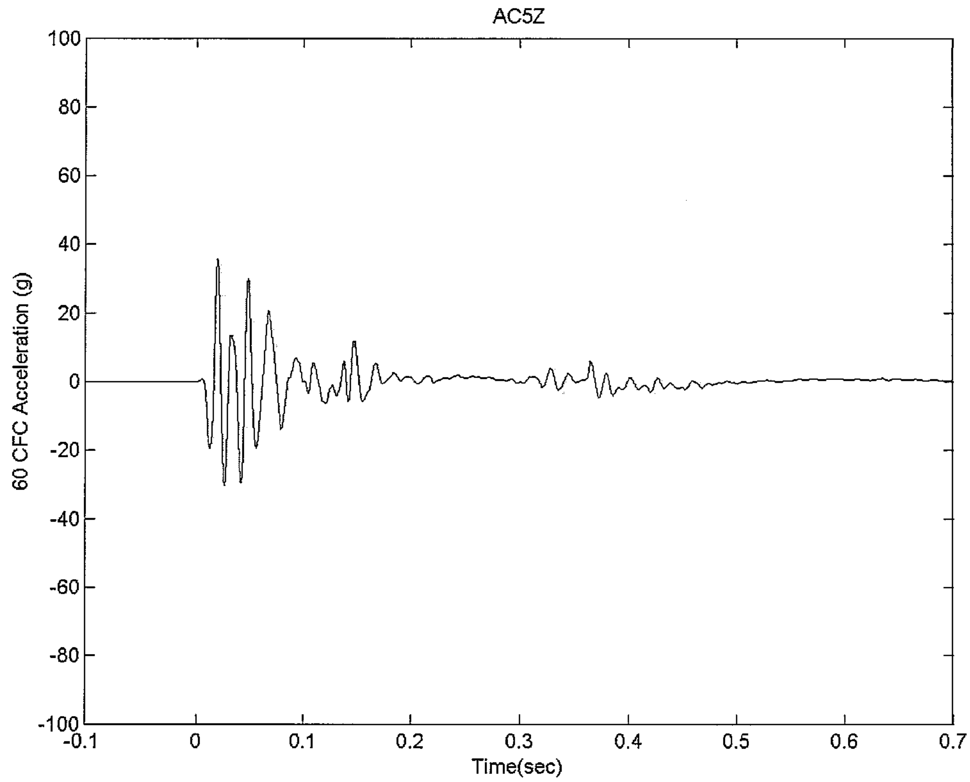

AC4Y
20
15
10
5
0
-5
-10
-15
-20
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)



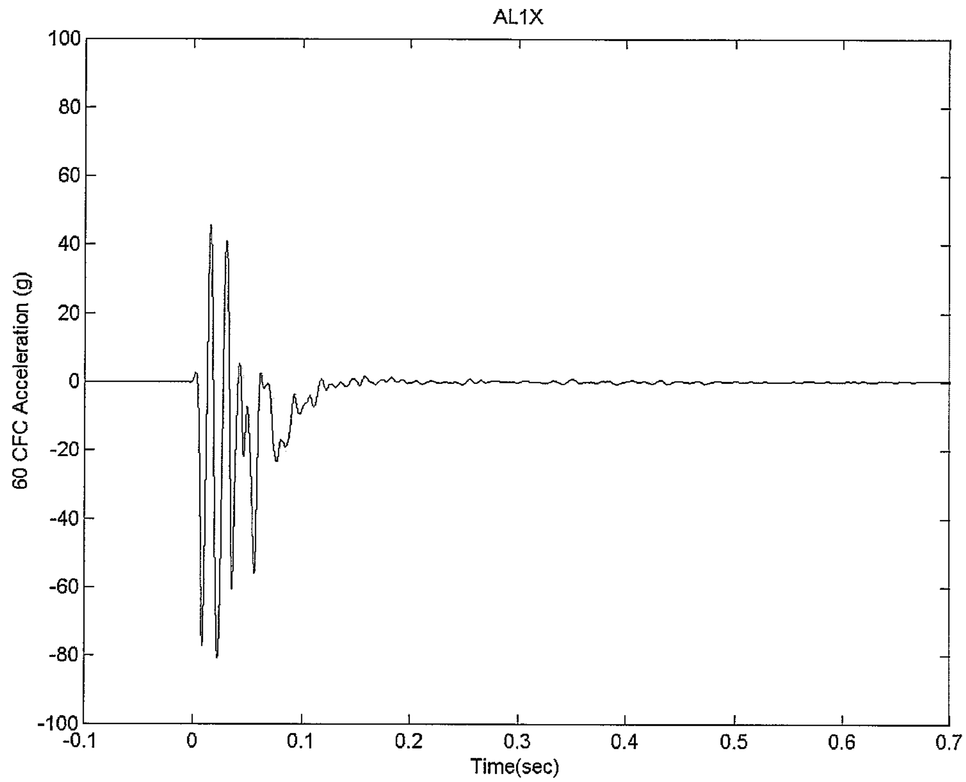
AC4Z
60 CFC Acceleration (g)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AC5X
60 CFC Acceleration (g)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

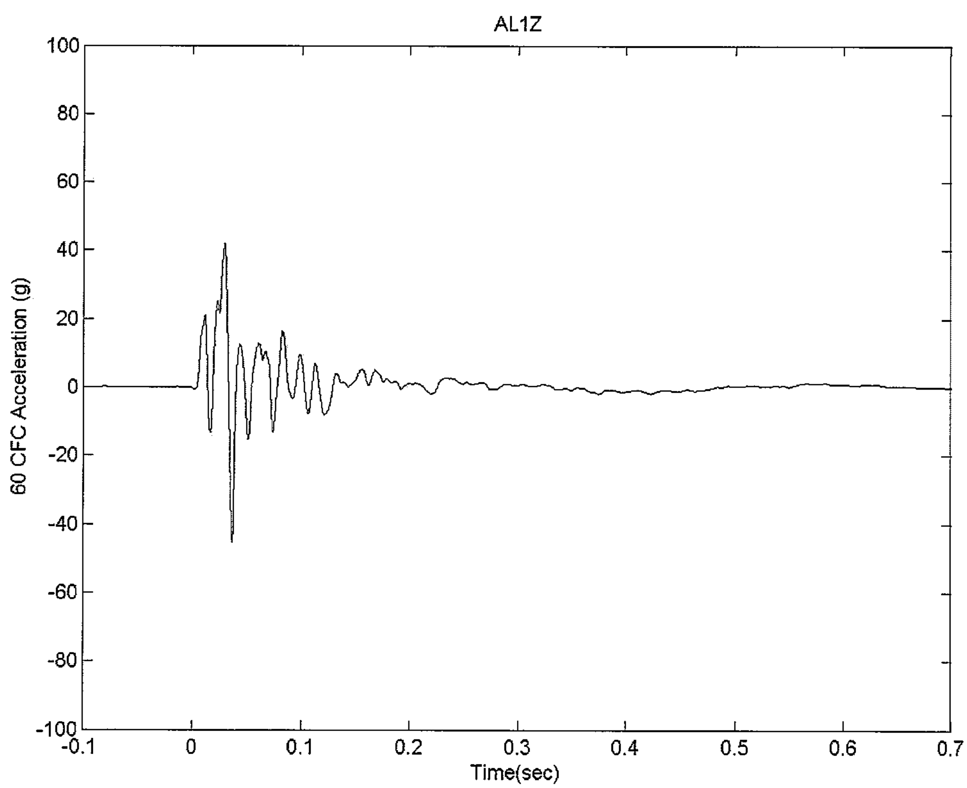

AC5Y
60 CFC Acceleration (g)
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)



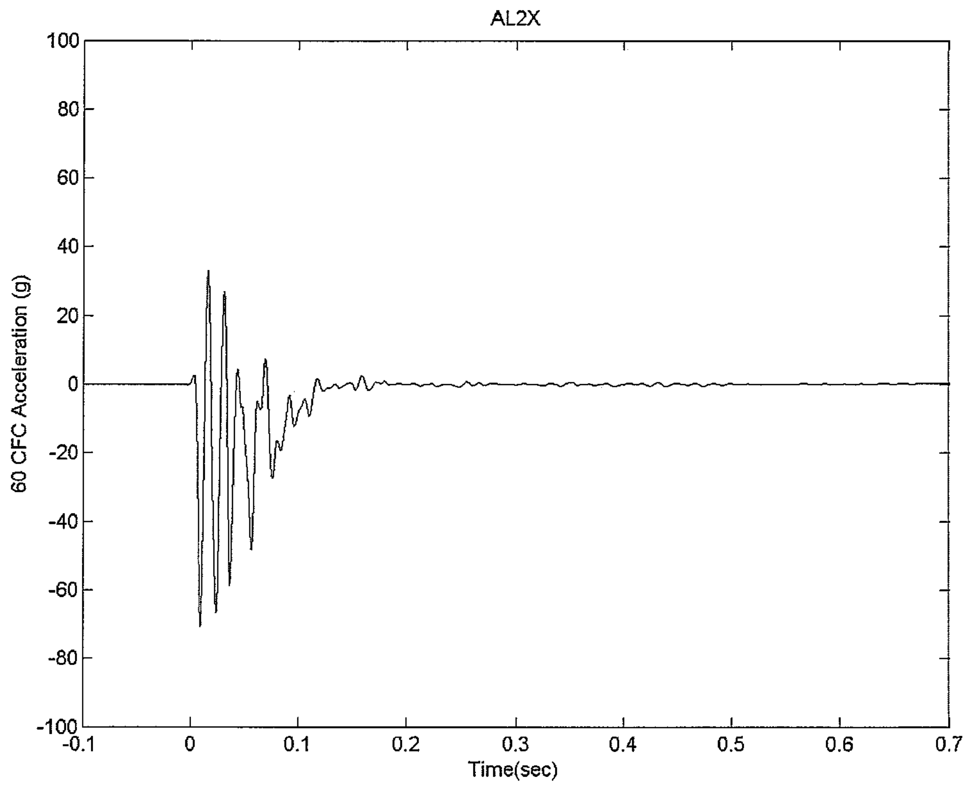
AC5Z
60 CFC Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

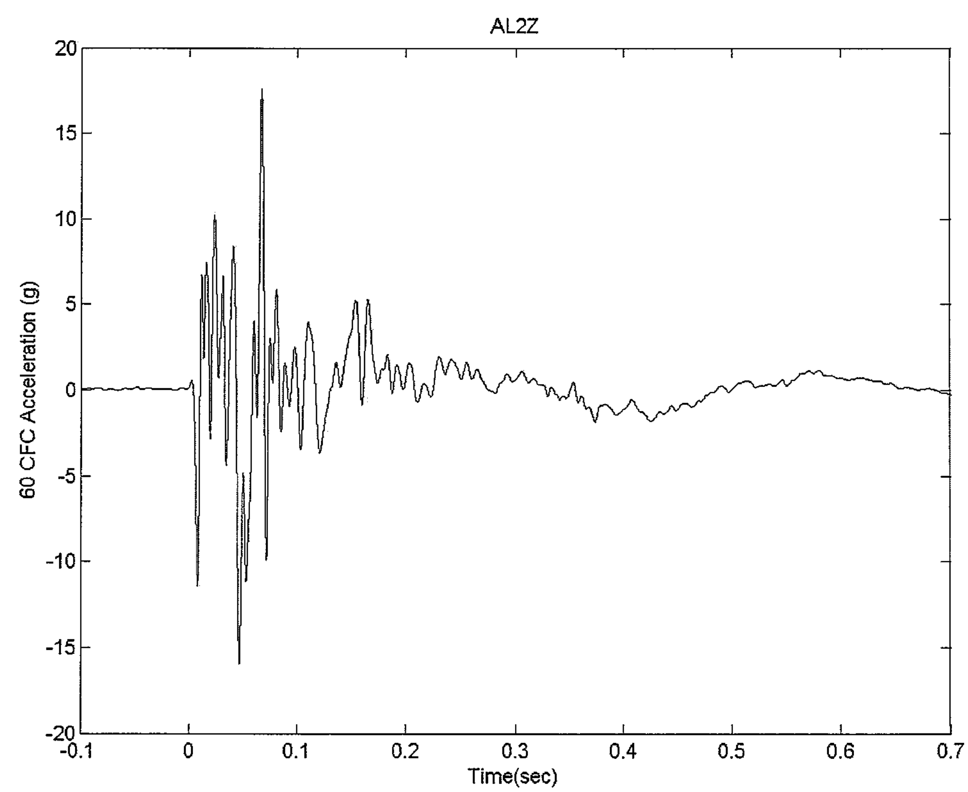


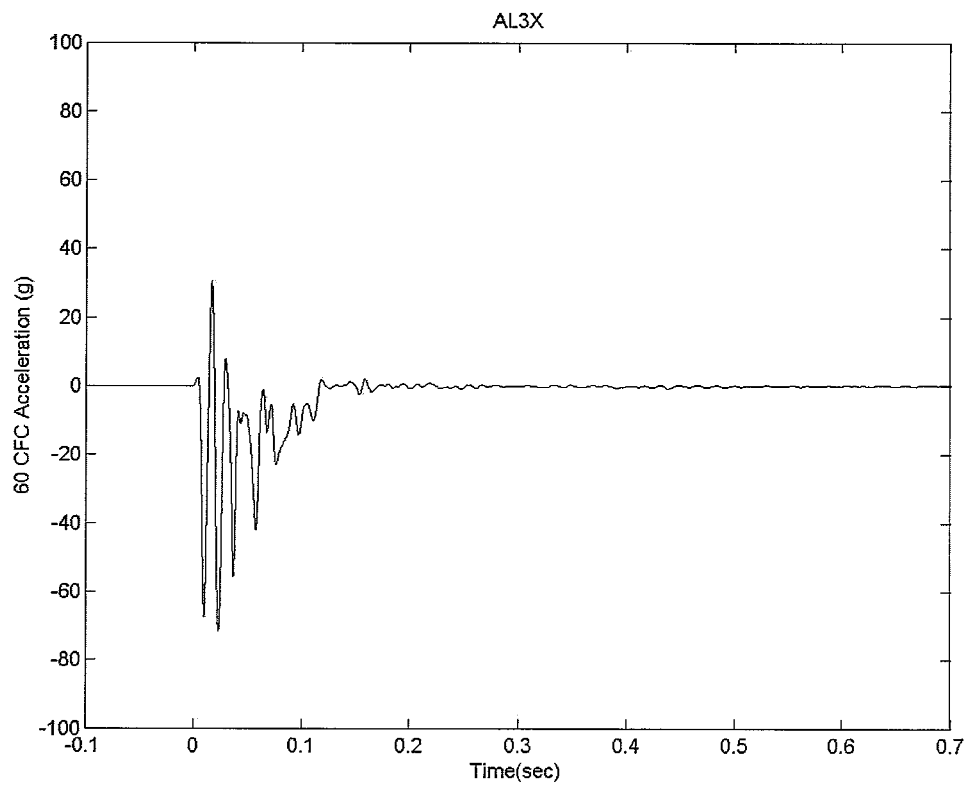
AL1X
100
80
60
40
20
0
-20
-40
-60
-80
-100
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

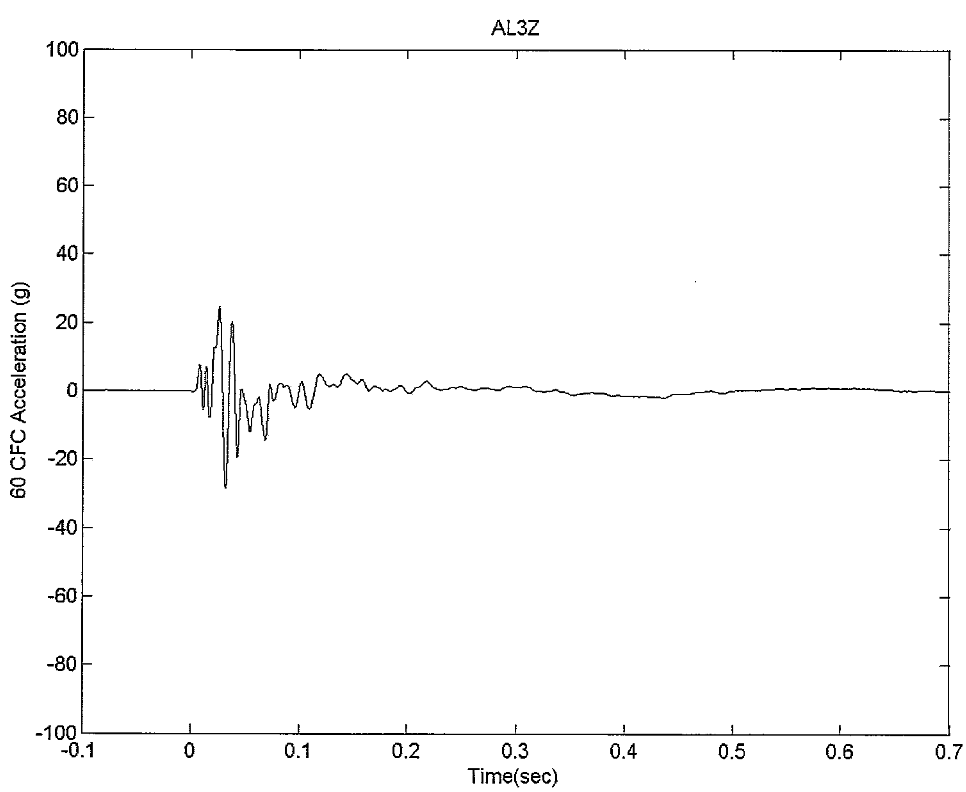


AL1Z
100
80
60
40
20
0
-20
-40
-60
-80
-100
60 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AL2X
60 CFC Acceleration (g)
Time(sec)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


AL2Z
60 CFC Acceleration (g)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


AL3X
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
60 CFC Acceleration (g)


AL3Z
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80
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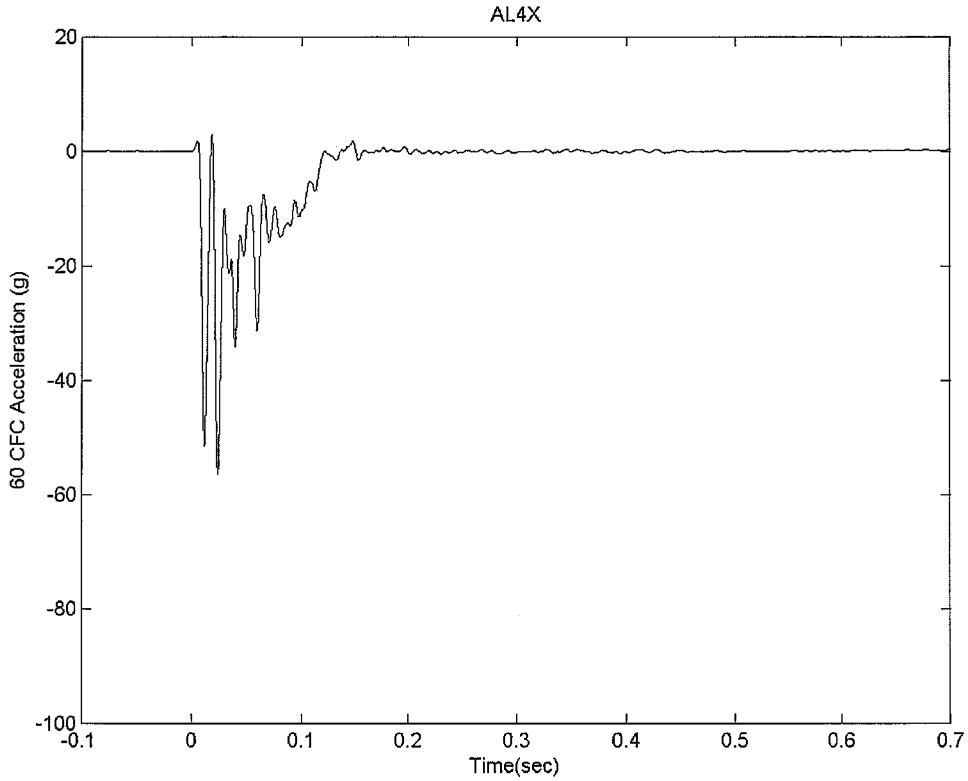
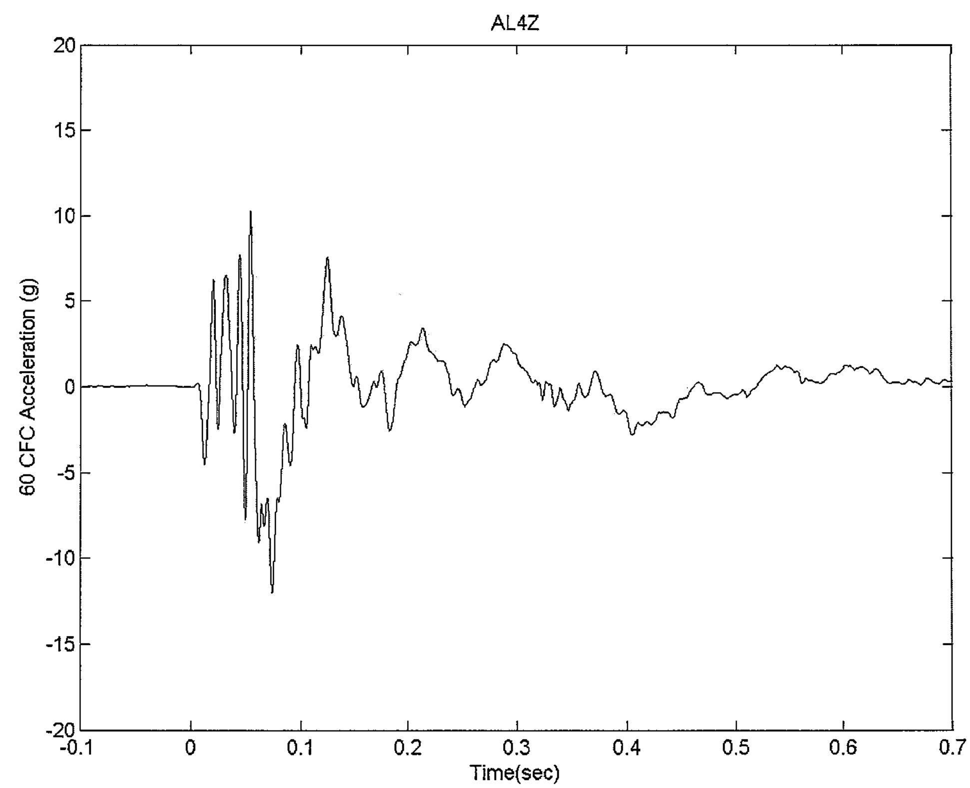
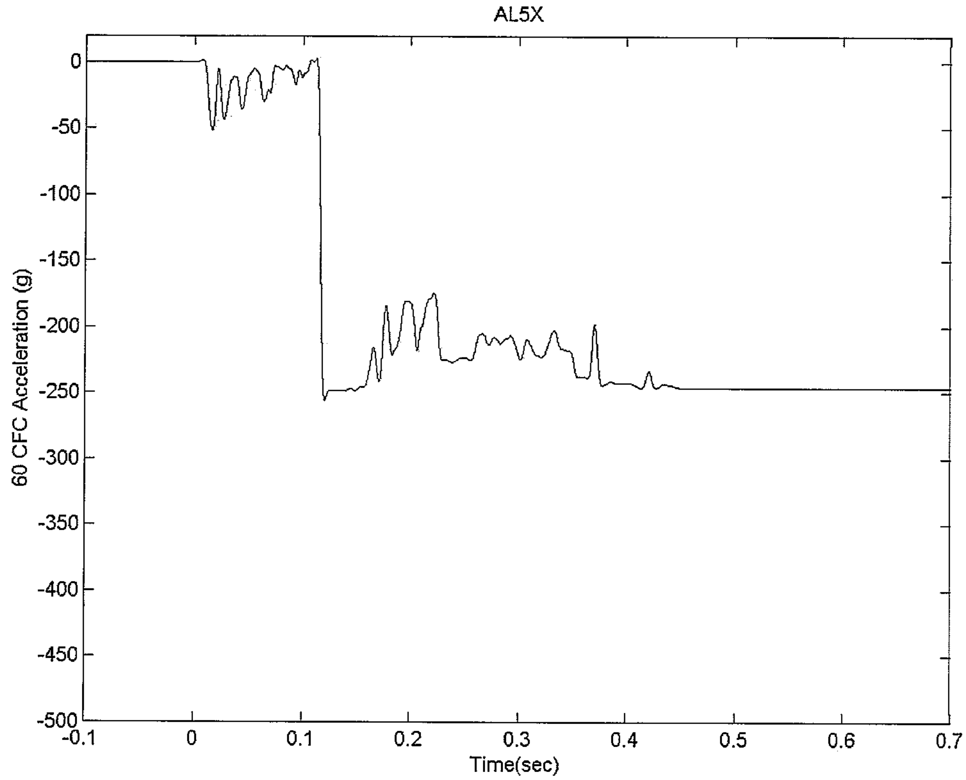
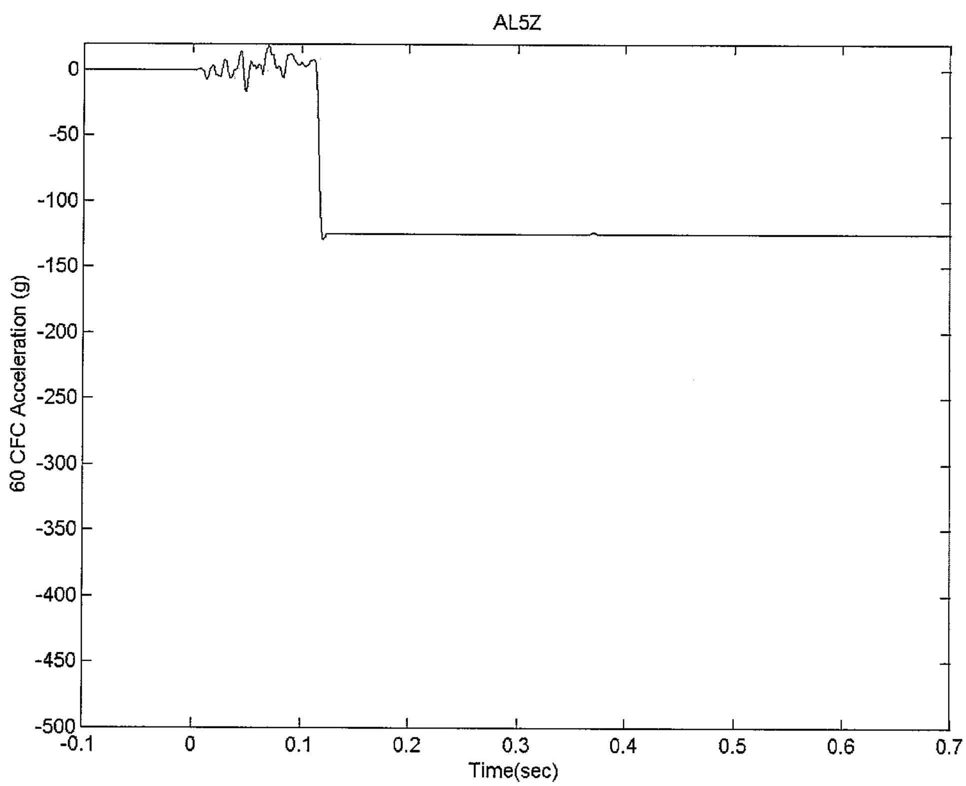
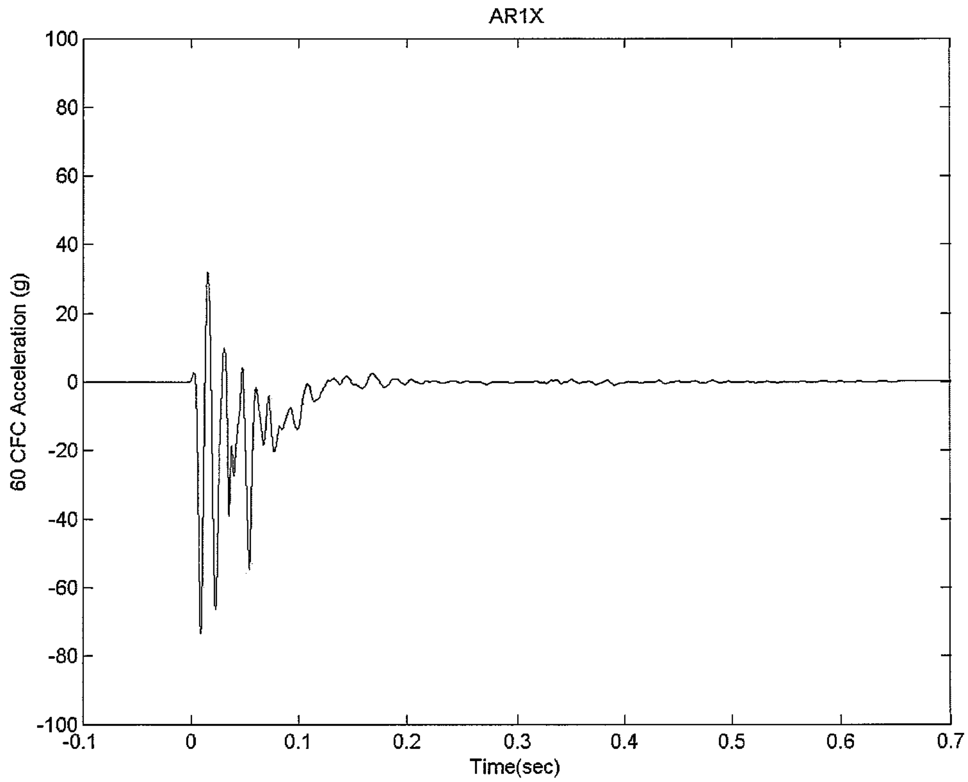
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
60 CFC Acceleration (g)


AL4X
60 CFC Acceleration (g)
Time(sec)


AL4Z
60 CFC Acceleration (g)
Time(sec)


AL5X
60 CFC Acceleration (g)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AL5Z
60 CFC Acceleration (g)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AR1X
100
80
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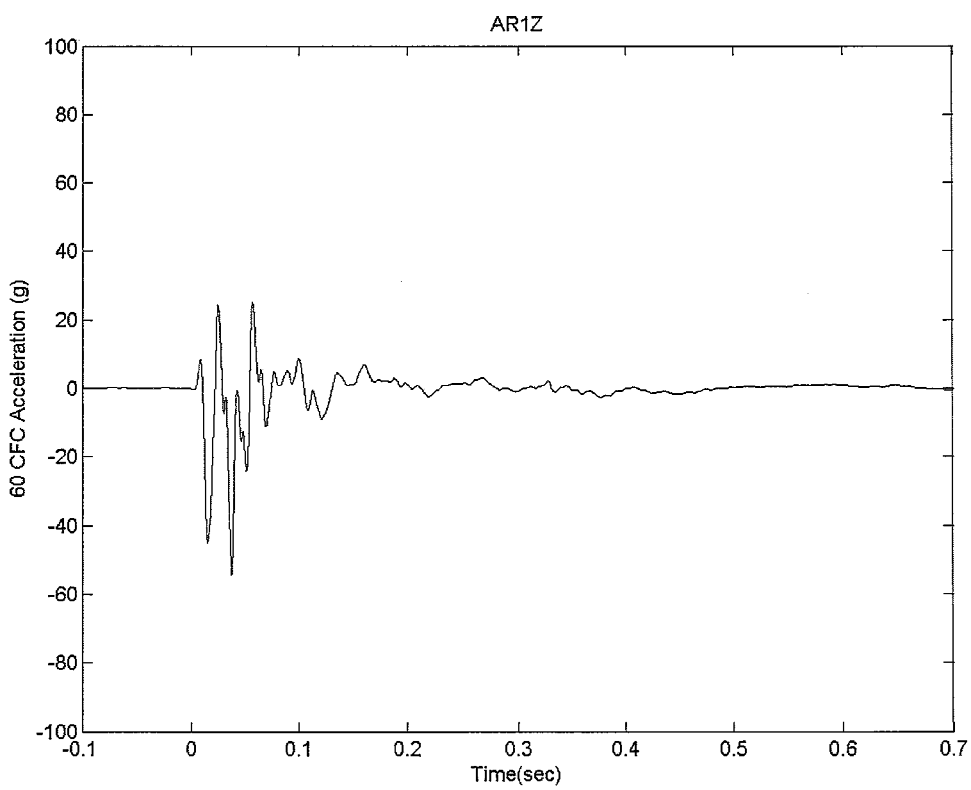
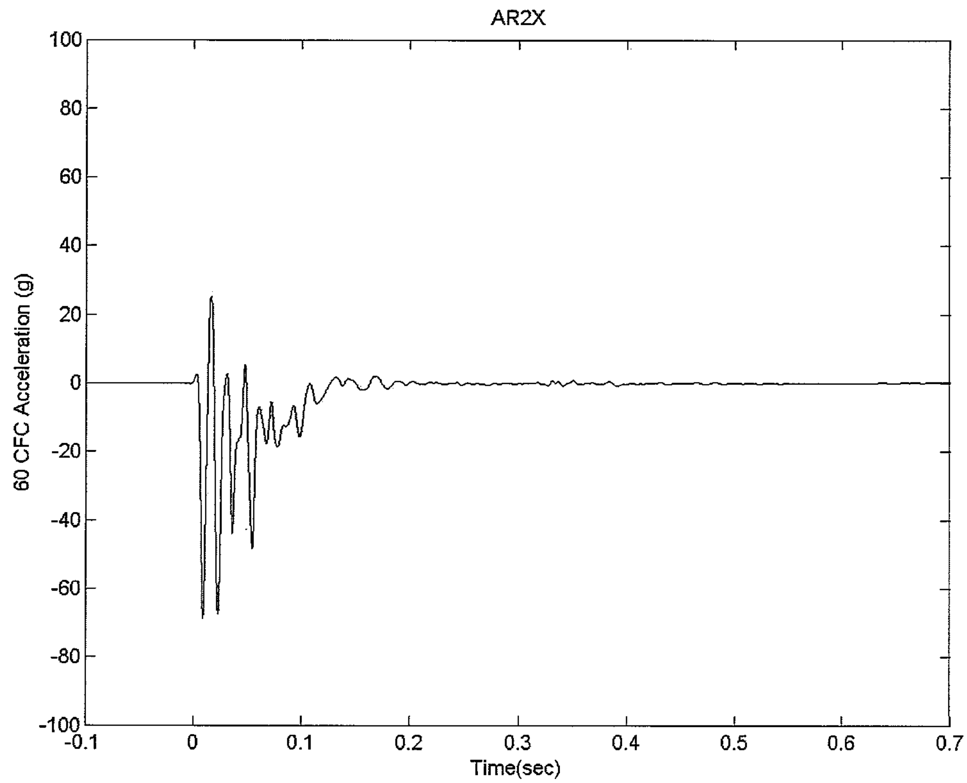
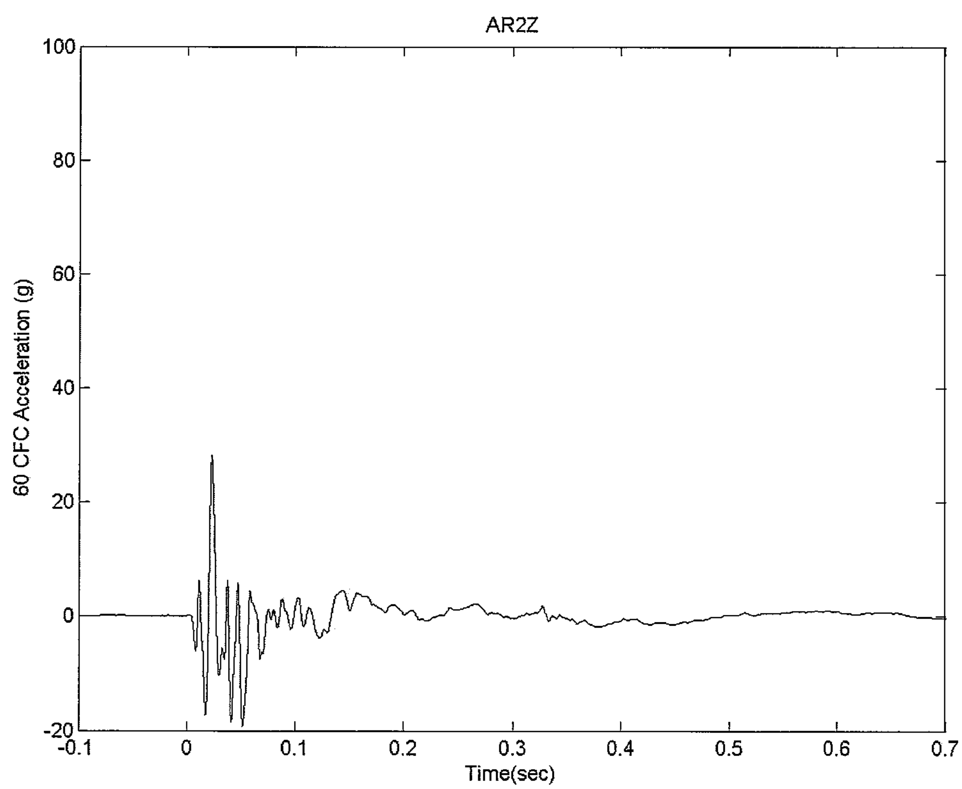
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
60 CFC Acceleration (g)


AR1Z
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
60 CFC Acceleration (g)


AR2X
60 CFC Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AR2Z
60 CFC Acceleration (g)
100
80
60
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0
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0.2
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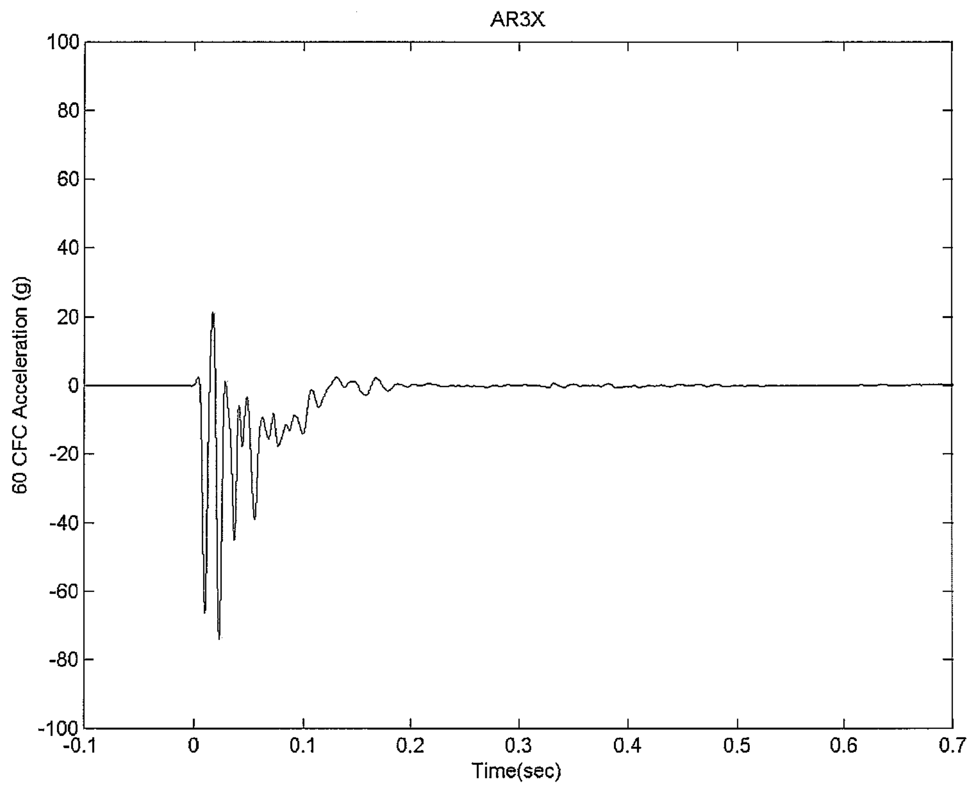
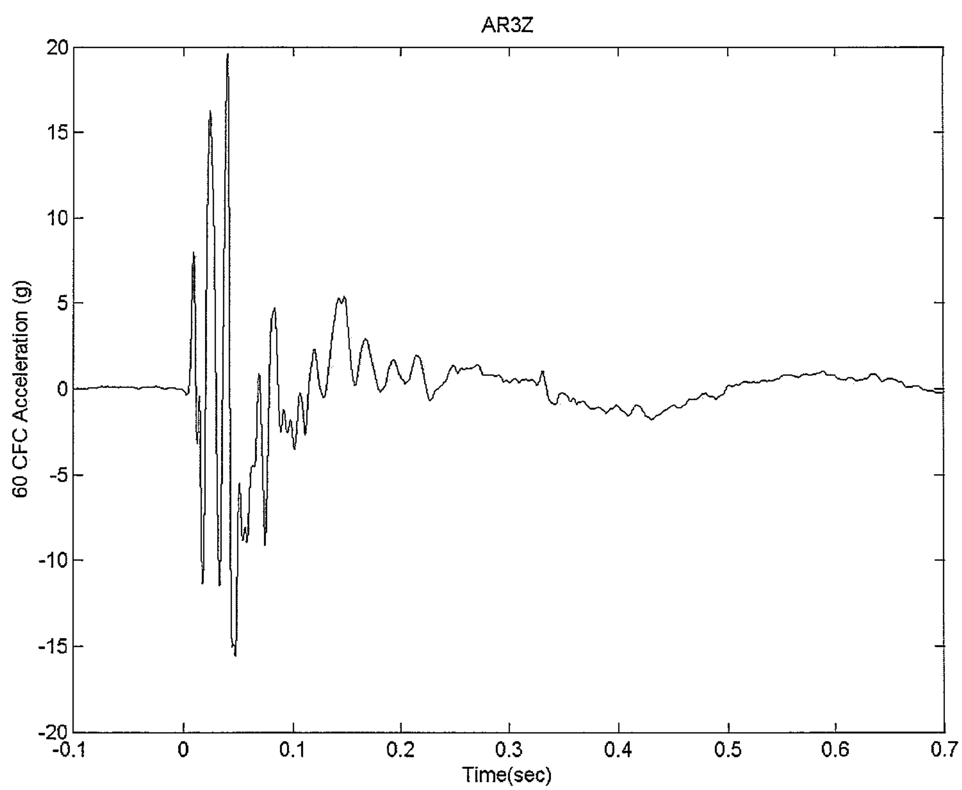
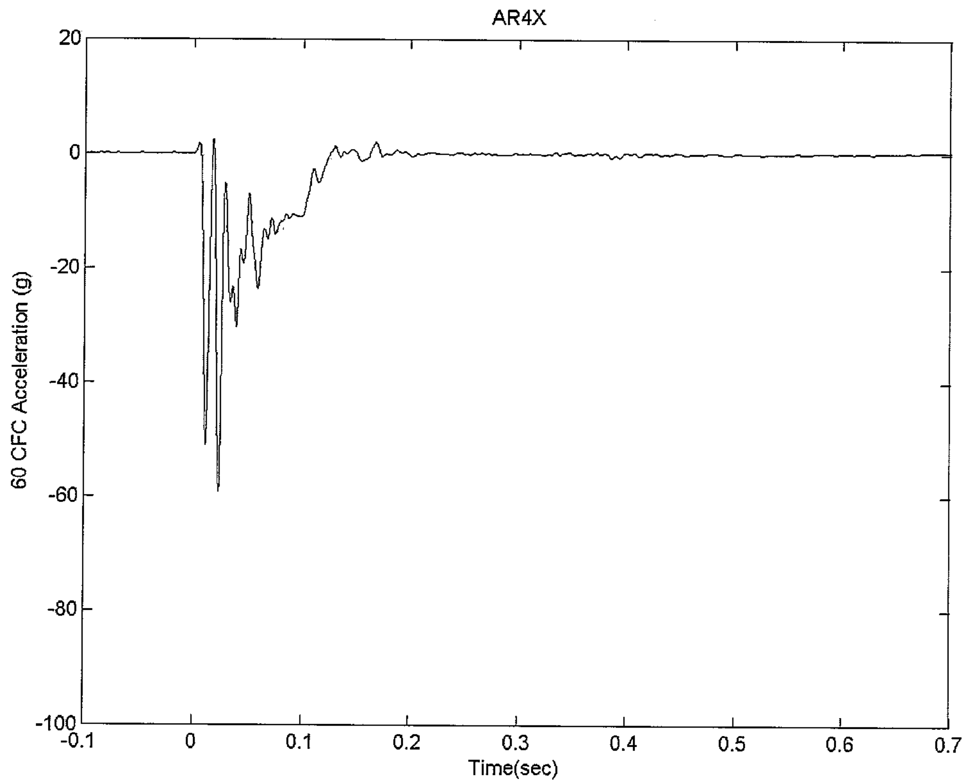
0.4
0.5
0.6
0.7
Time(sec)


AR3X
60 CFC Acceleration (g)
Time(sec)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


AR3Z
60 CFC Acceleration (g)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


AR4X
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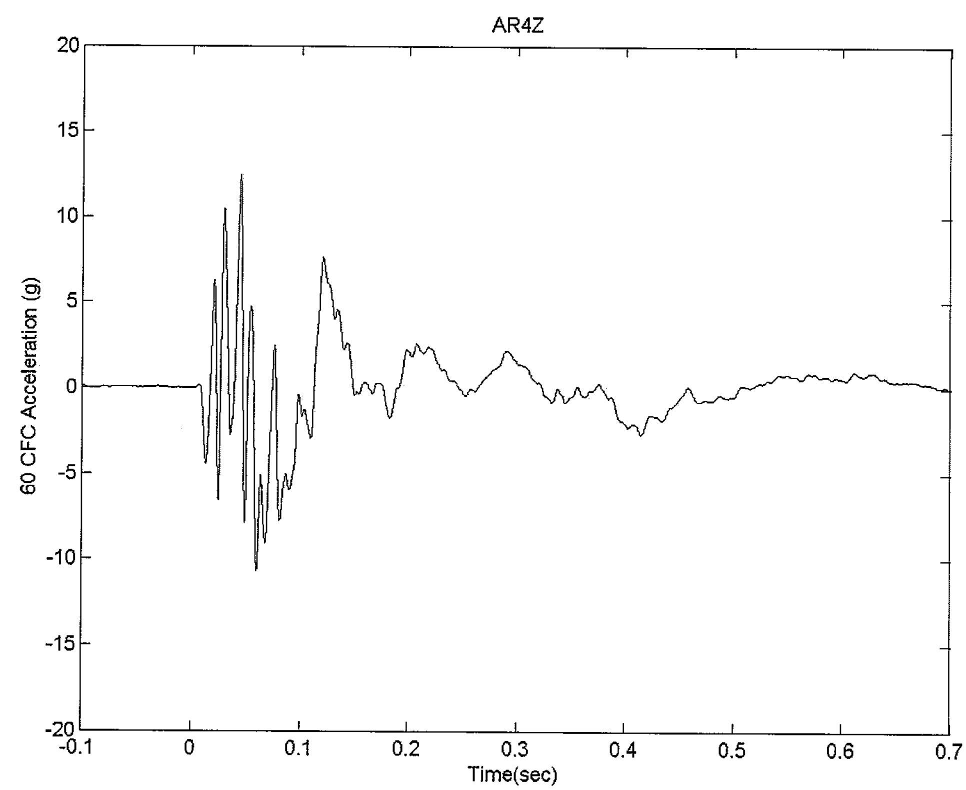
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
60 CFC Acceleration (g)


AR4Z
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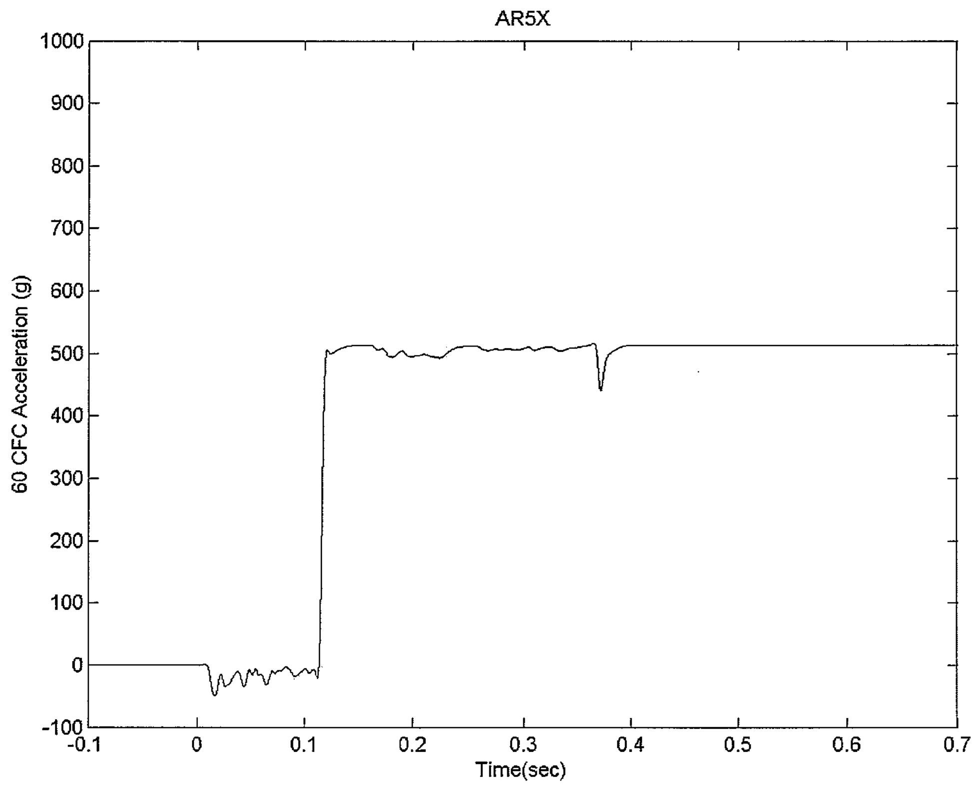
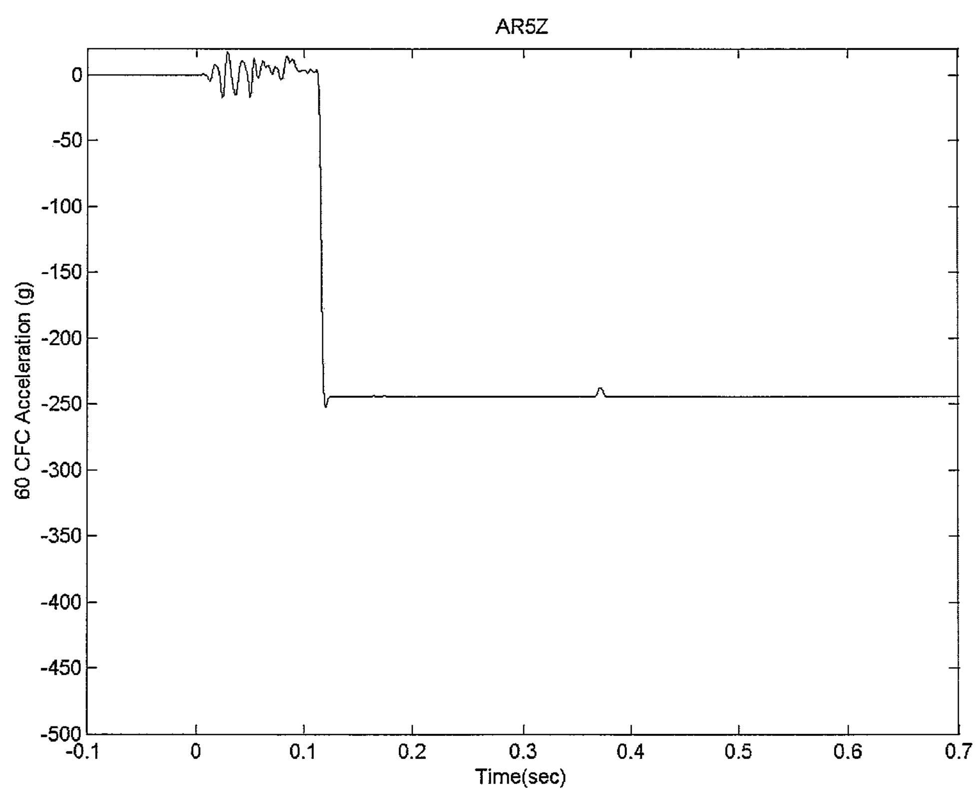
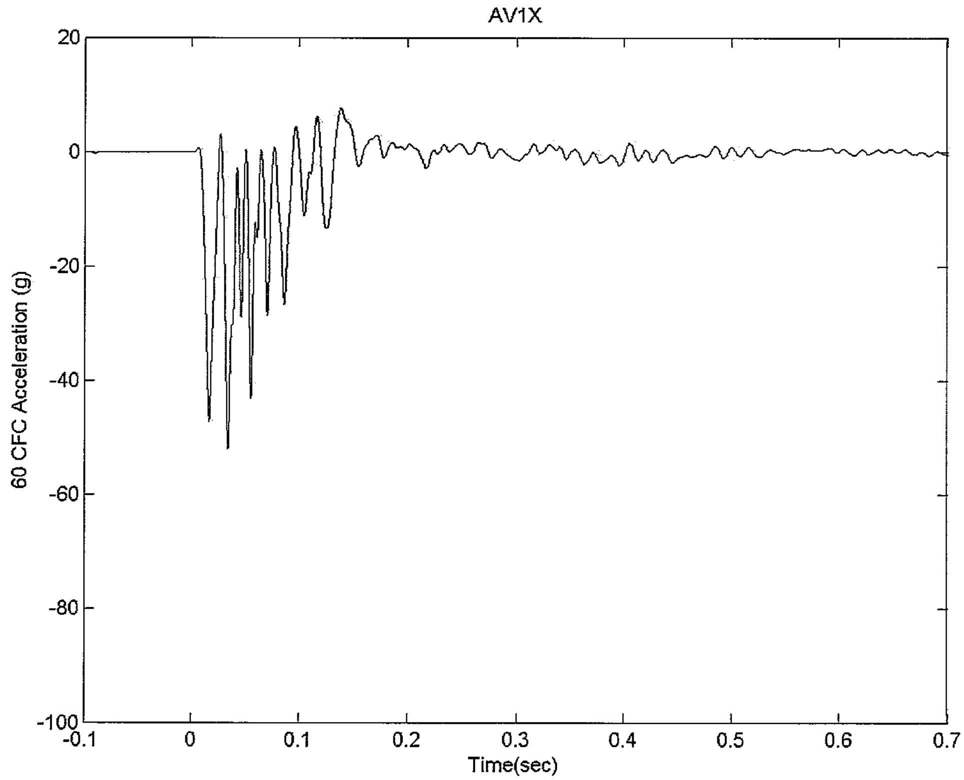
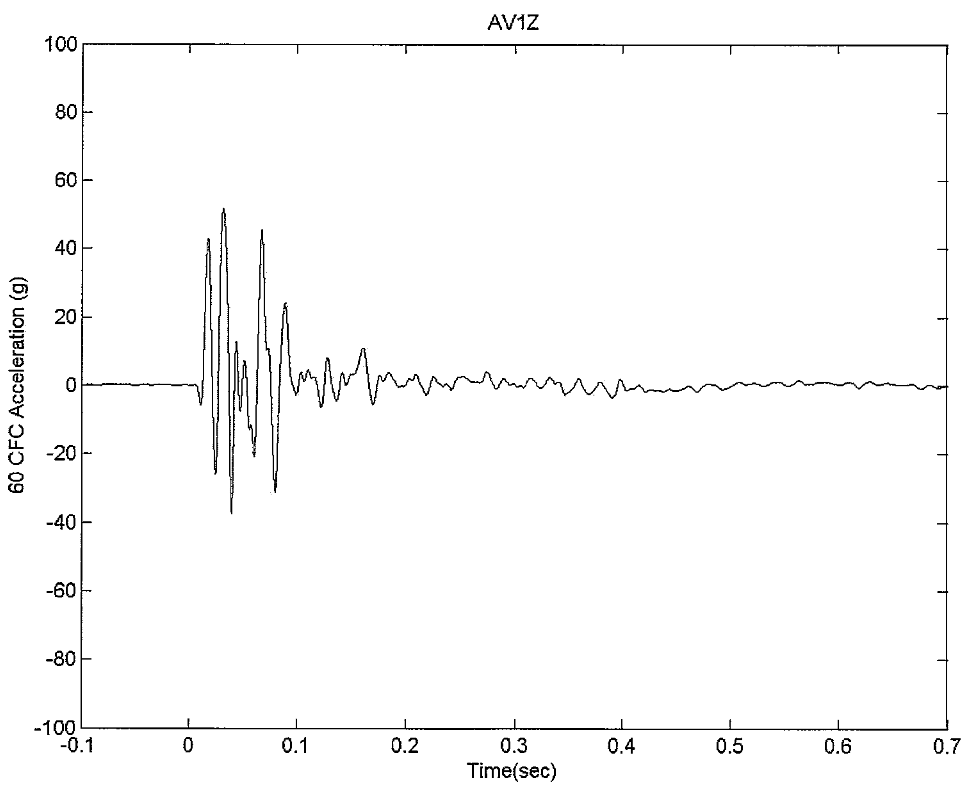
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
60 CFC Acceleration (g)


AR5X
60 CFC Acceleration (g)
1000
900
800
700
600
500
400
300
200
100
0
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

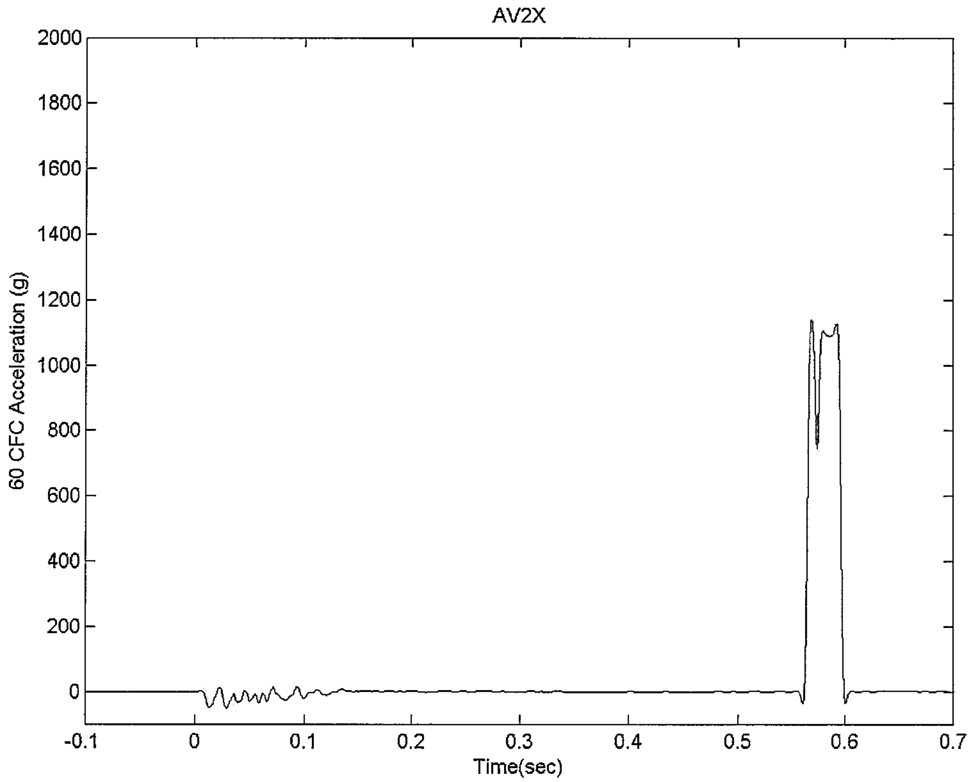

AR5Z
60 CFC Acceleration (g)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

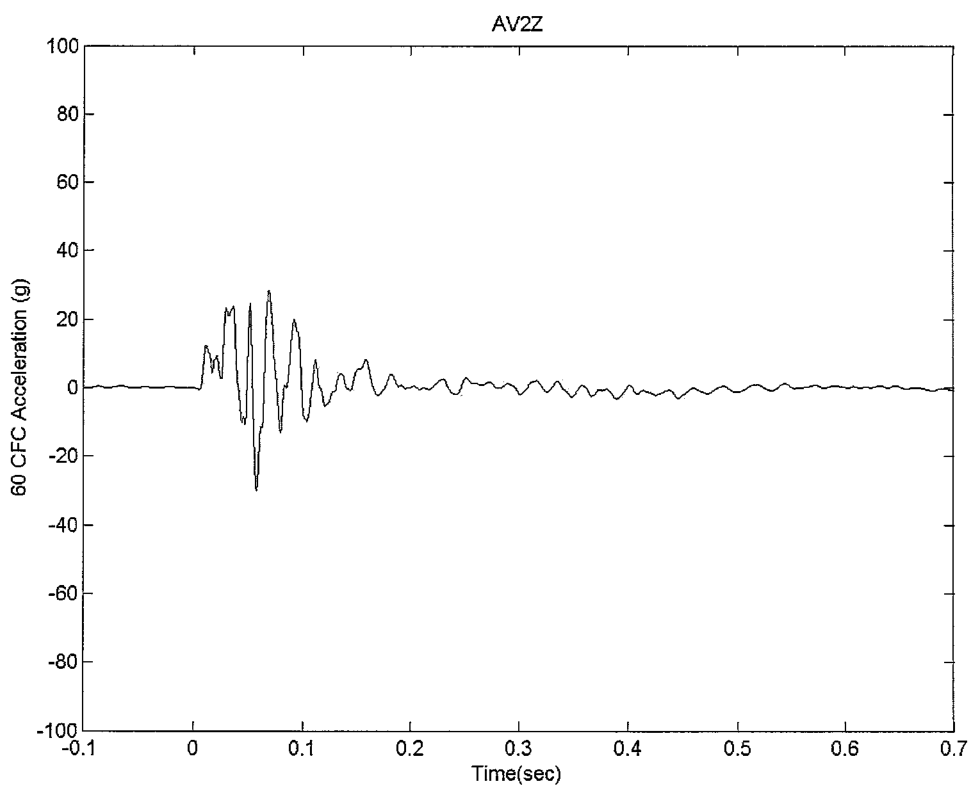


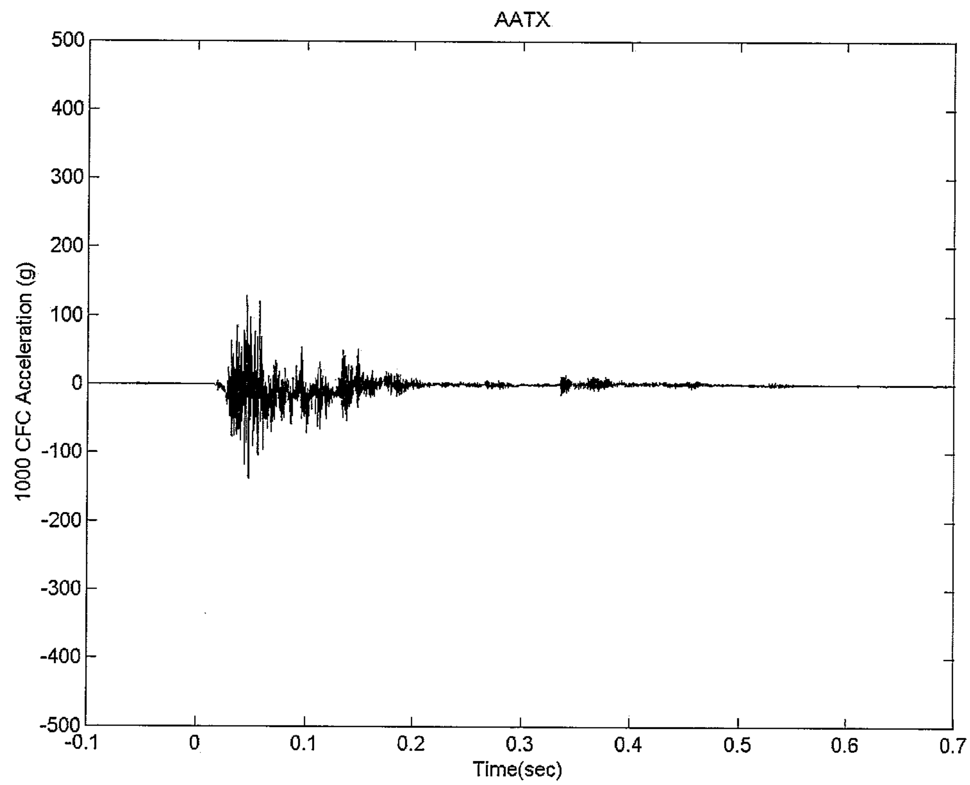
AV1X
60 CFC Acceleration (g)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

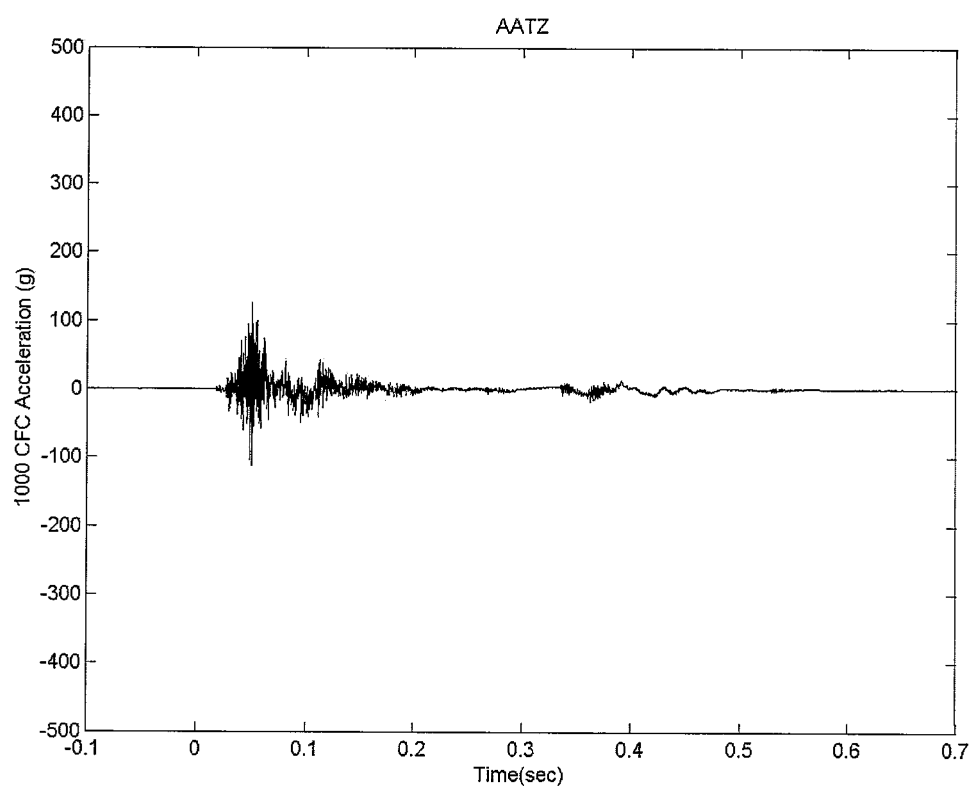


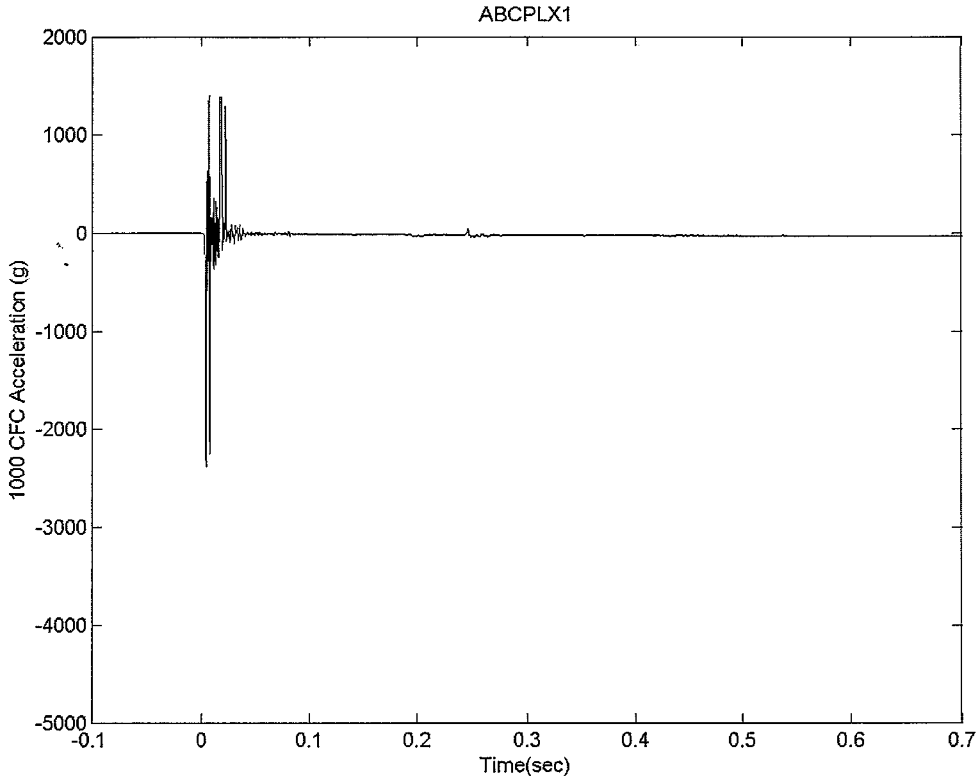
AV1Z
60 CFC Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

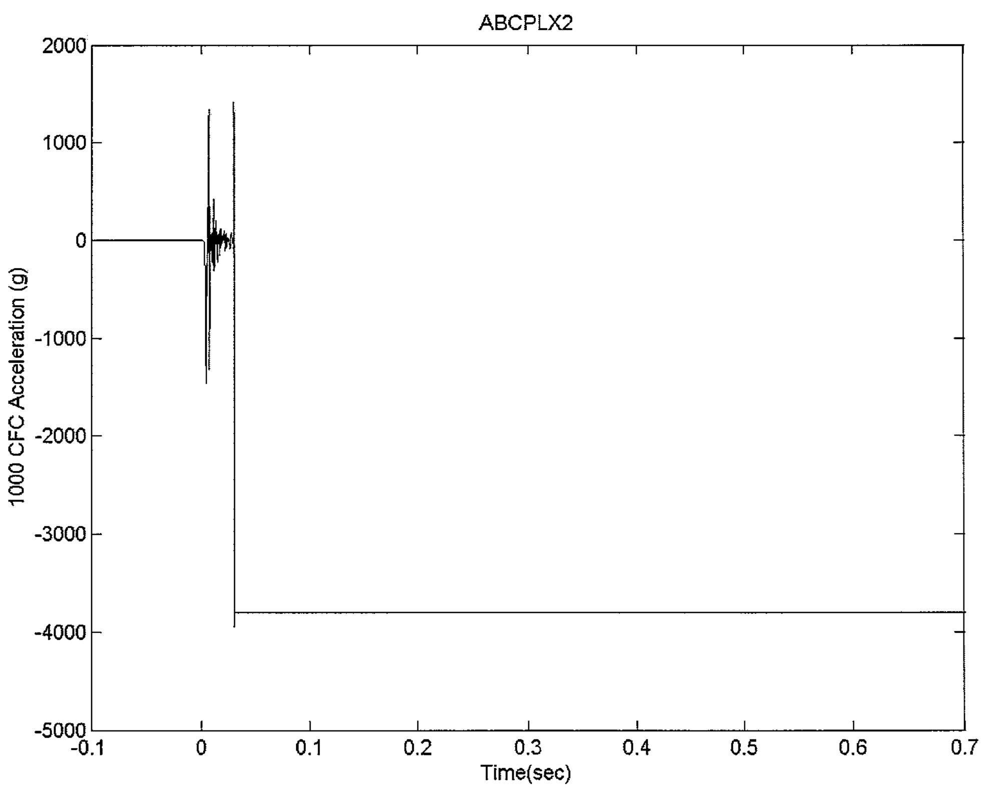

AV2X
60 CFC Acceleration (g)
Time(sec)

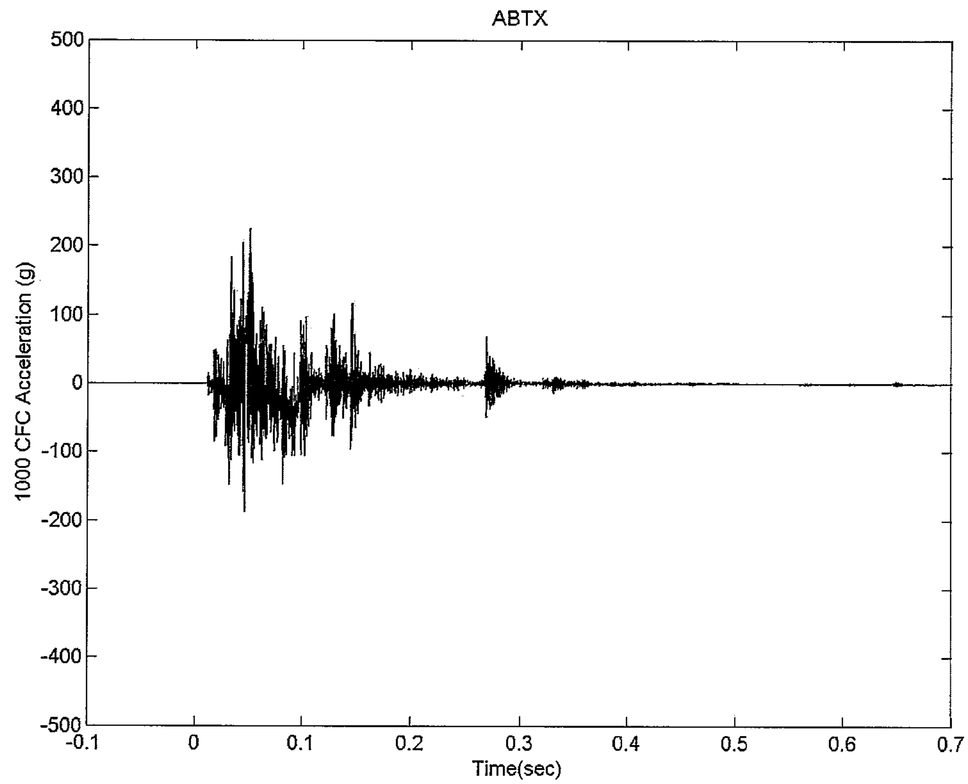

AV2Z
60 CFC Acceleration (g)
Time(sec)


AATX
1000 CFC Acceleration (g)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AATZ
1000 CFC Acceleration (g)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


ABCPLX1
2000
1000
0
-1000
-2000
-3000
-4000
-5000
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


ABCPLX2
2000
1000
0
-1000
-2000
-3000
-4000
-5000
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


ABTX
1000 CFC Acceleration (g)
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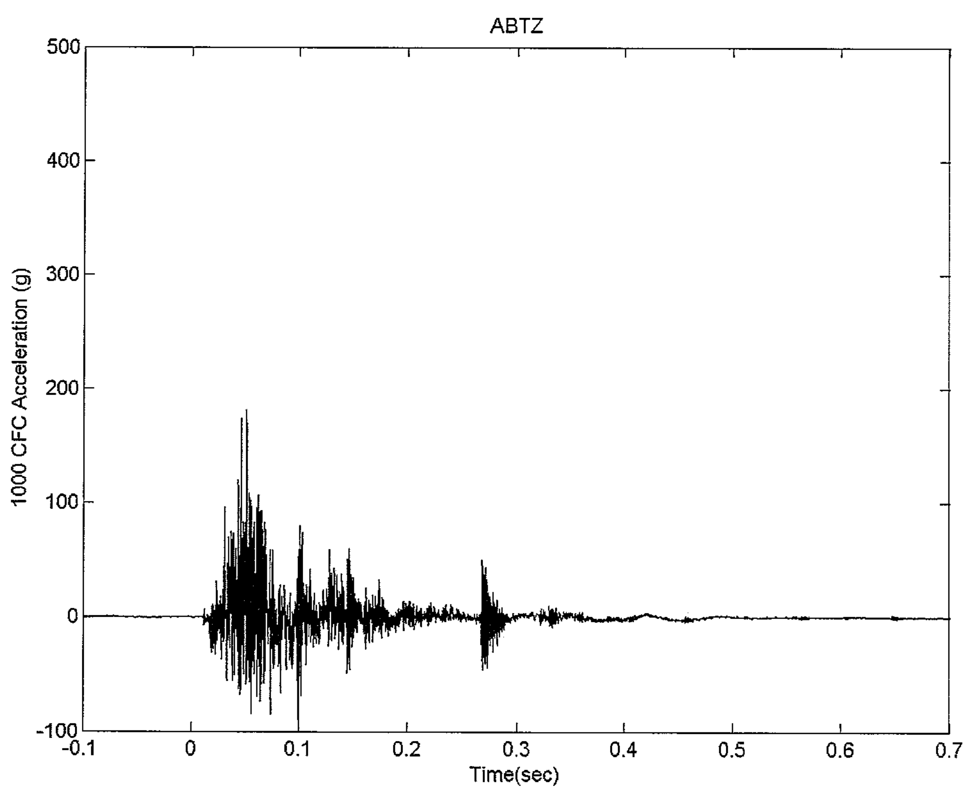
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


ABTZ
1000 CFC Acceleration (g)
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300
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-0.1
0
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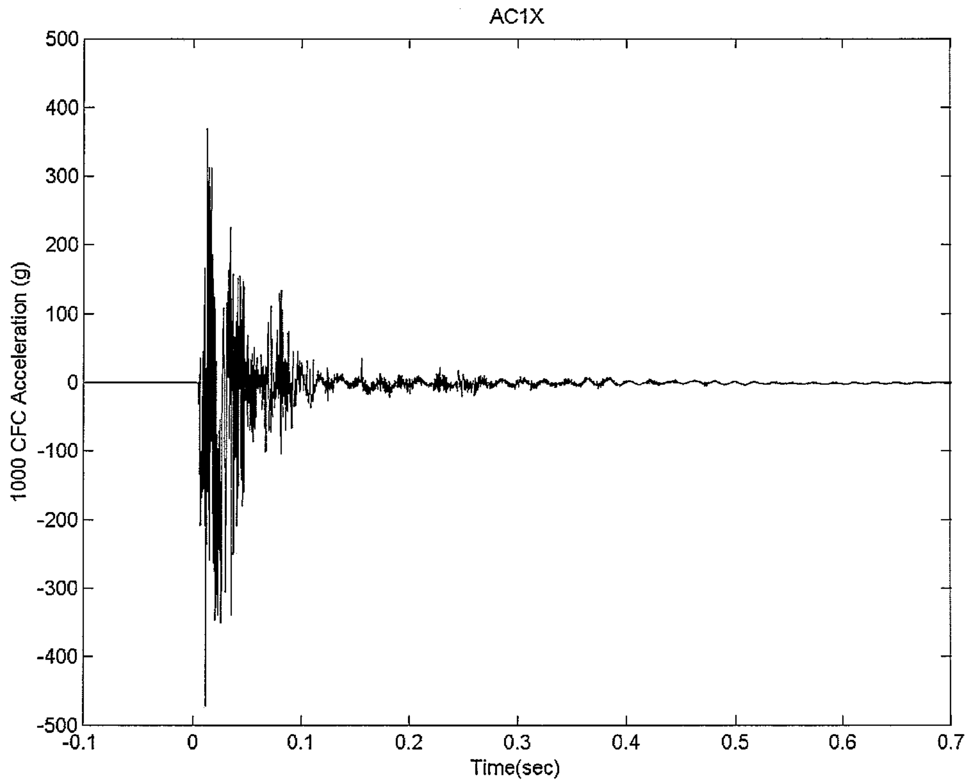
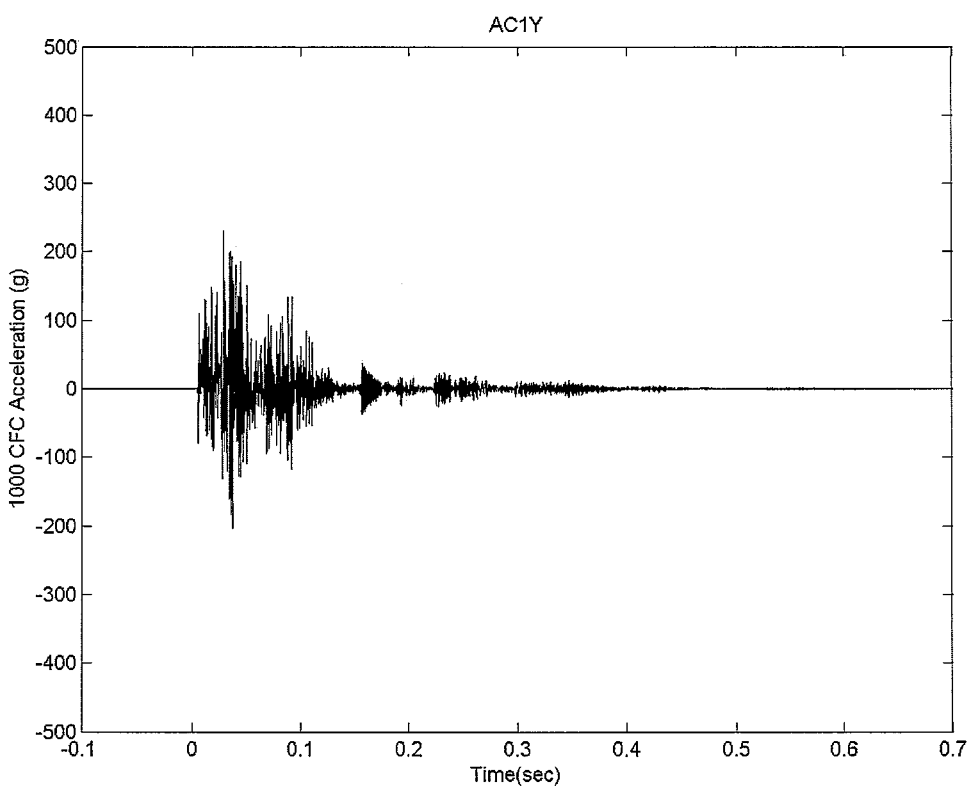
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AC1X
1000 CFC Acceleration (g)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AC1Y
1000 CFC Acceleration (g)
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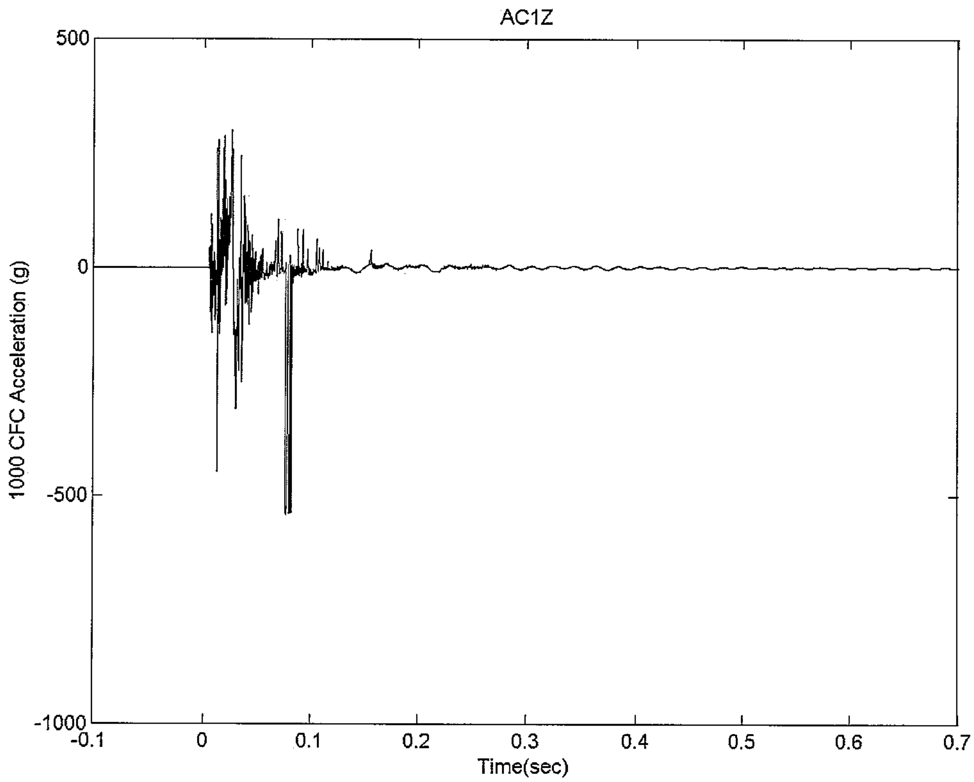
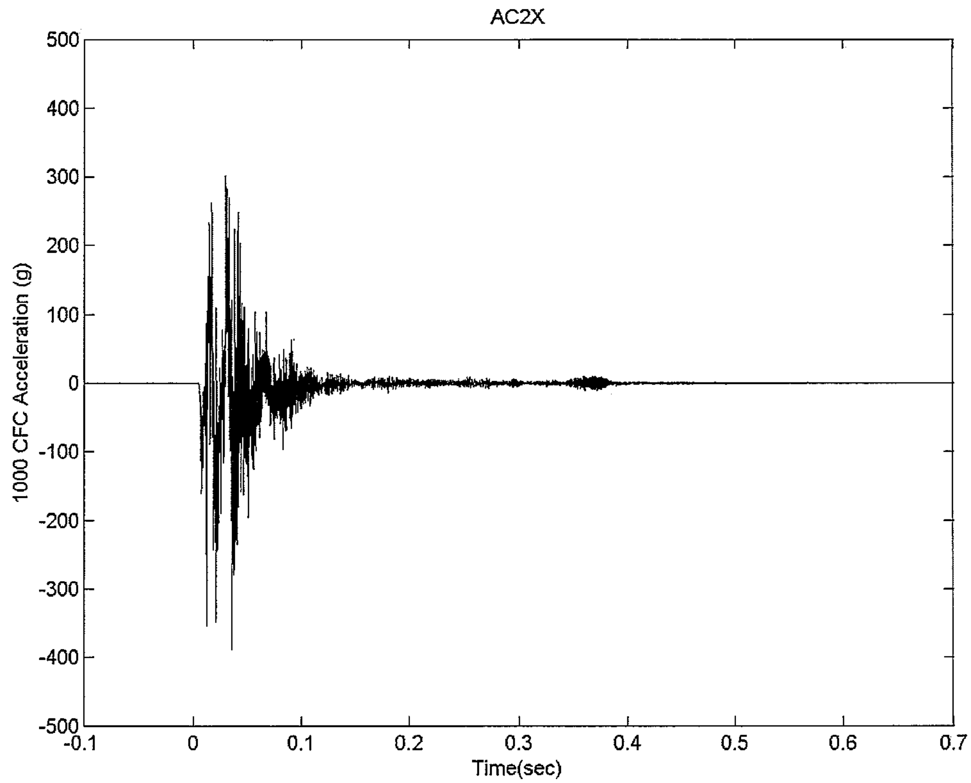
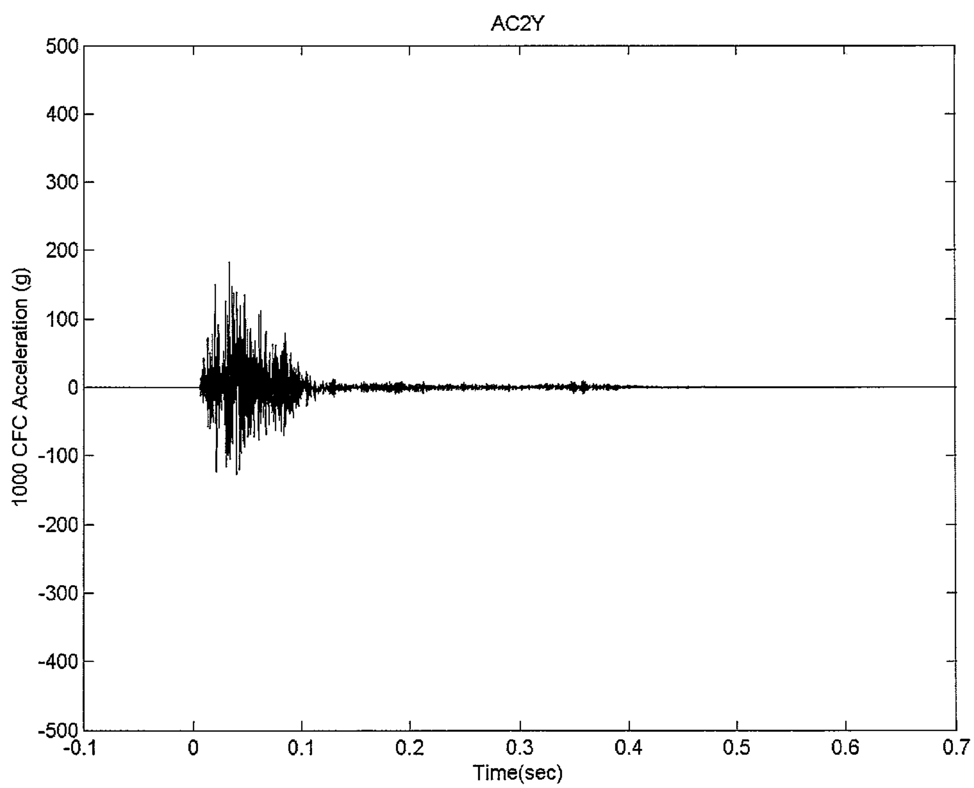
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AC1Z
500
0
-500
-1000
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AC2X
1000 CFC Acceleration (g)
Time(sec)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


AC2Y
1000 CFC Acceleration (g)
Time(sec)
500
400
300
200
100
0
-100
-200
-300
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-500
-0.1
0
0.1
0.2
0.3
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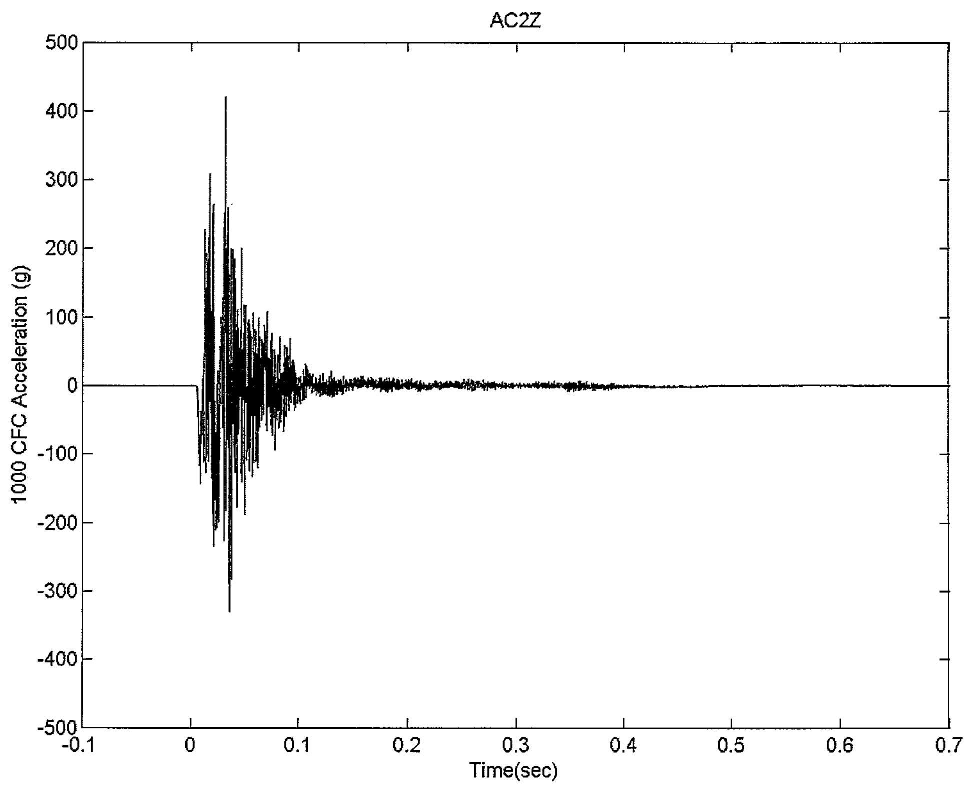
0.7


AC2Z
1000 CFC Acceleration (g)
500
400
300
200
100
0
-100
-200
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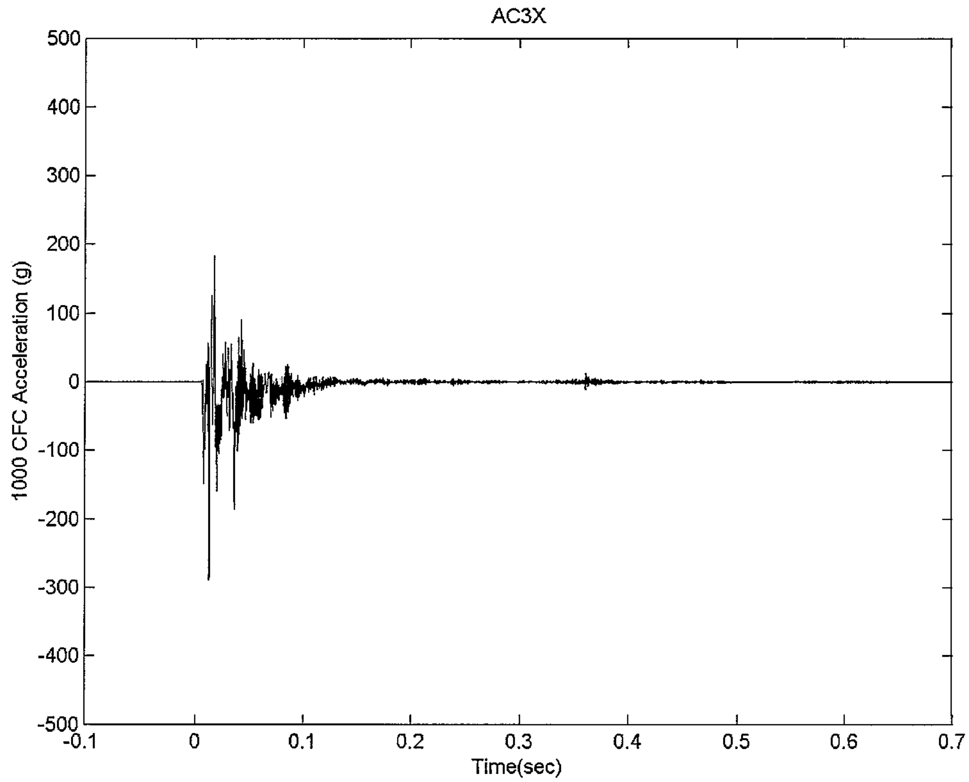
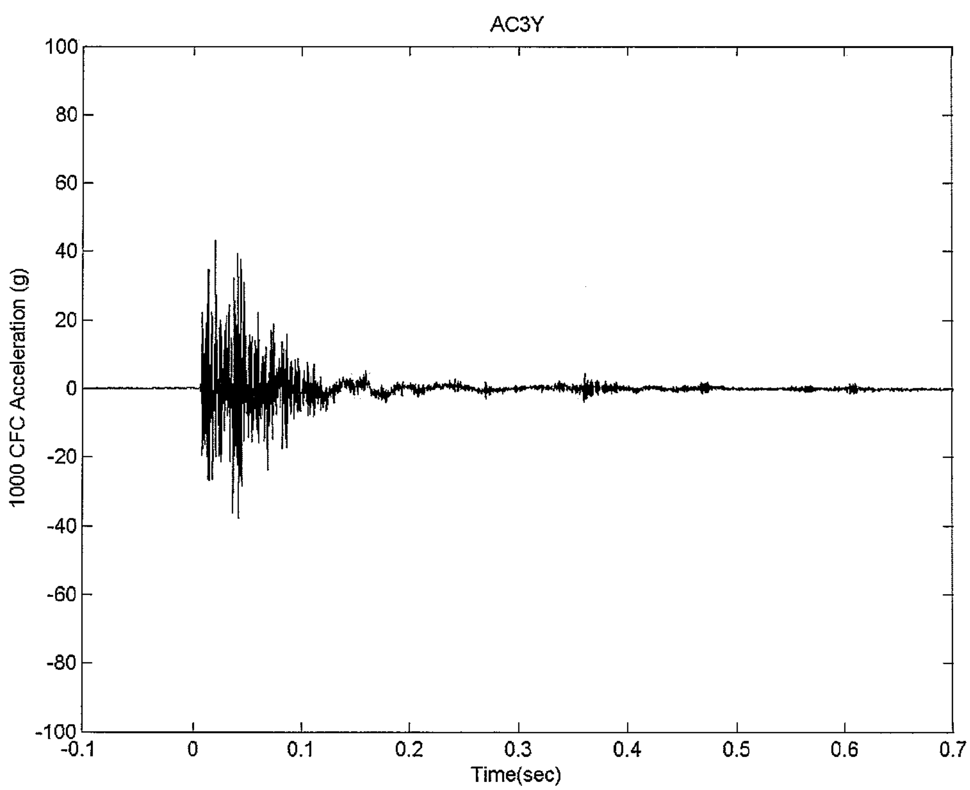
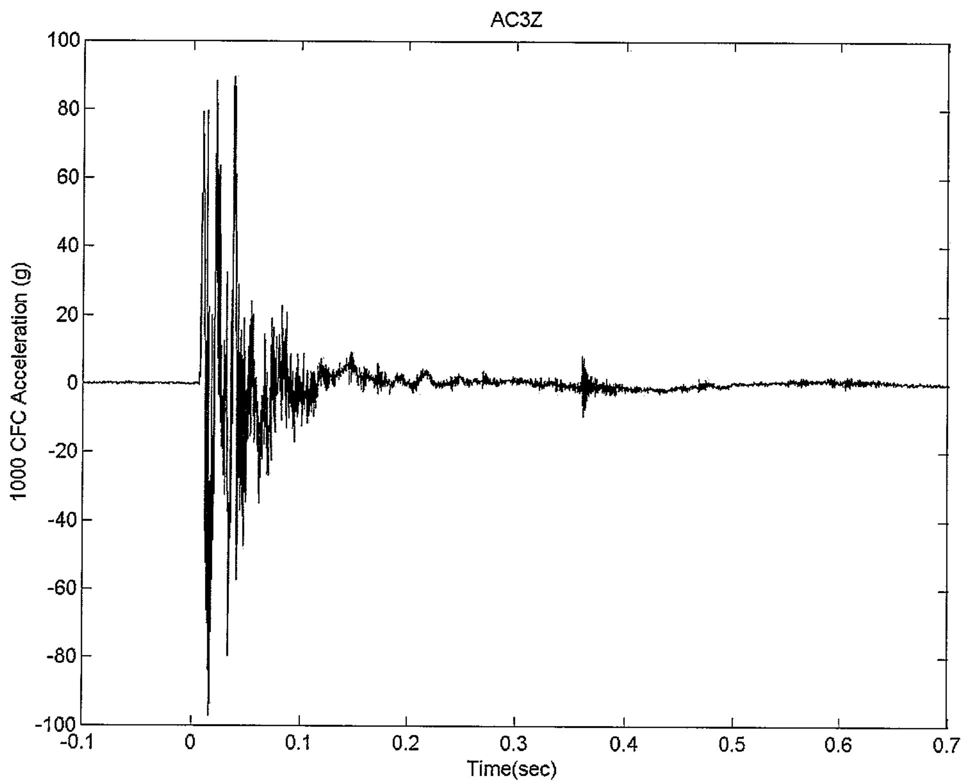
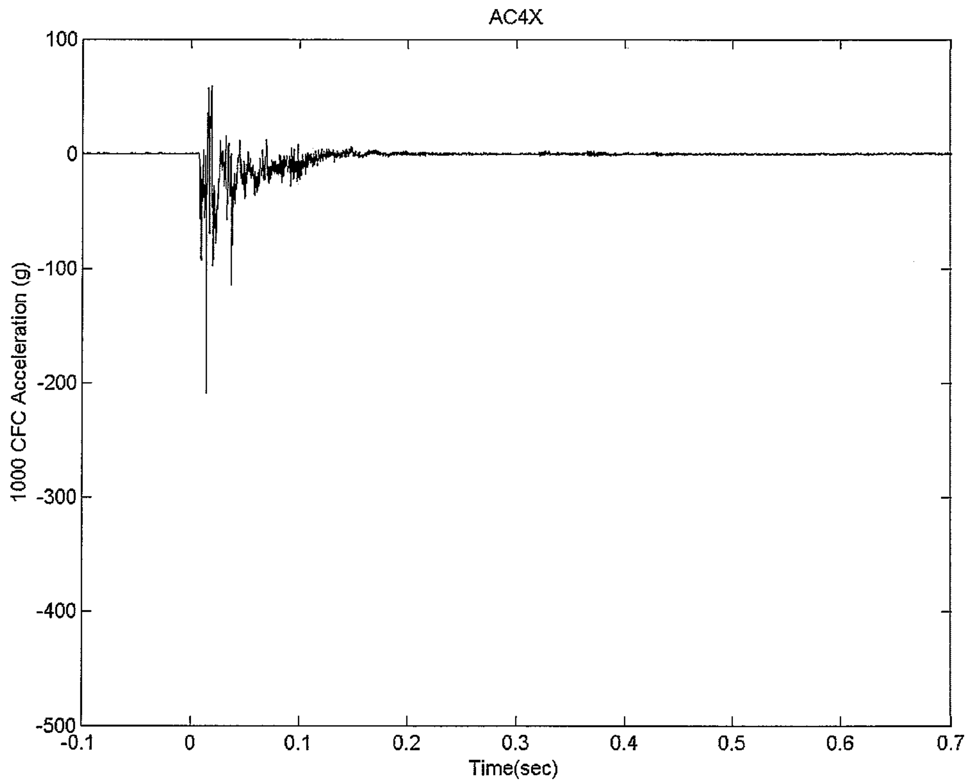
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

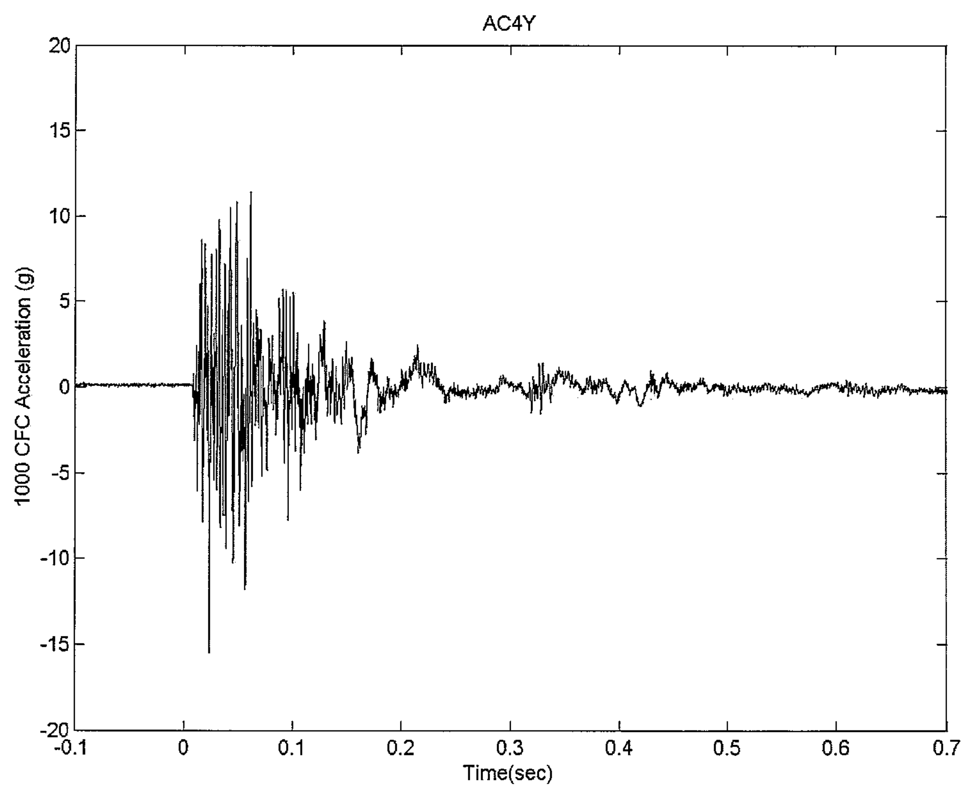

AC3X
1000 CFC Acceleration (g)
Time(sec)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

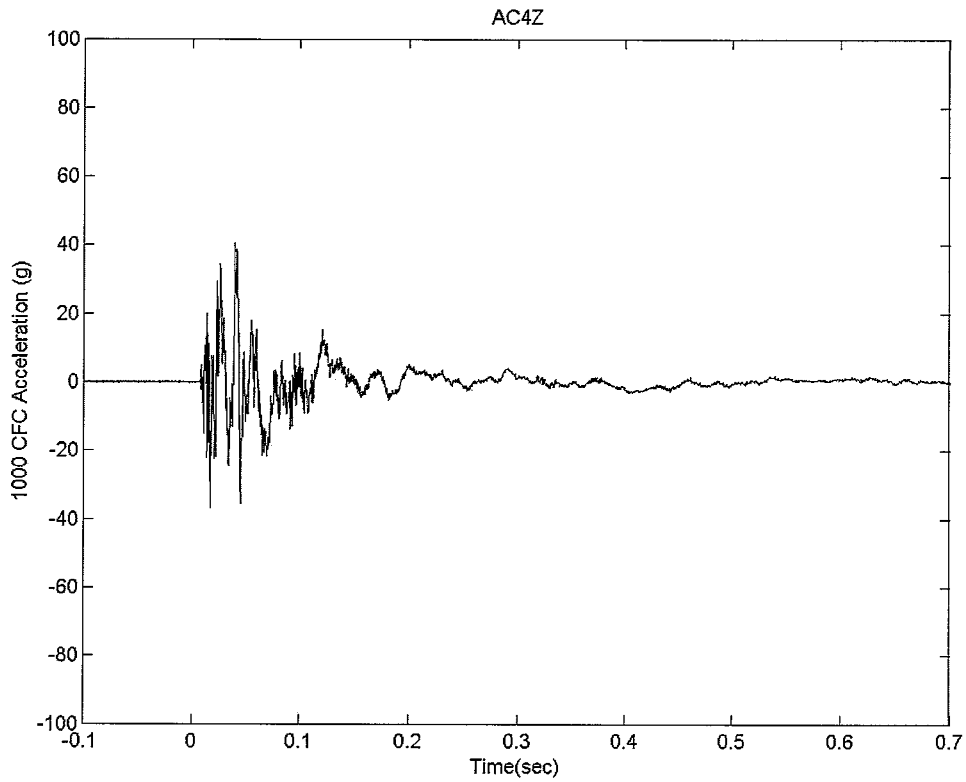

AC3Y
1000 CFC Acceleration (g)
Time(sec)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

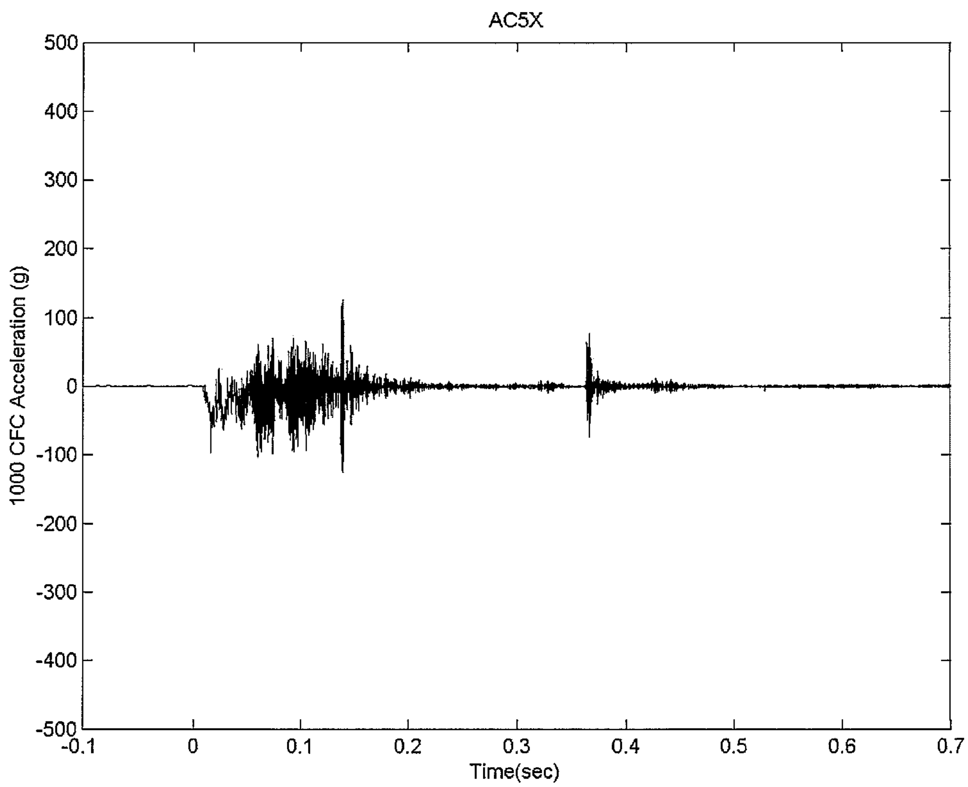


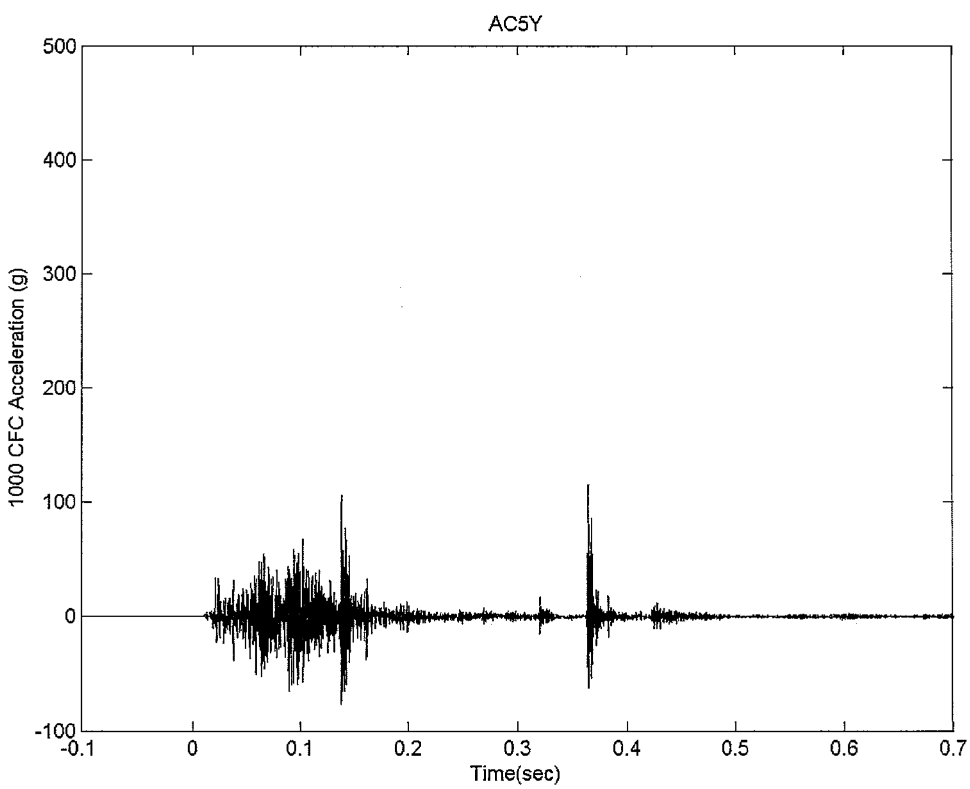
AC3Z
1000 CFC Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

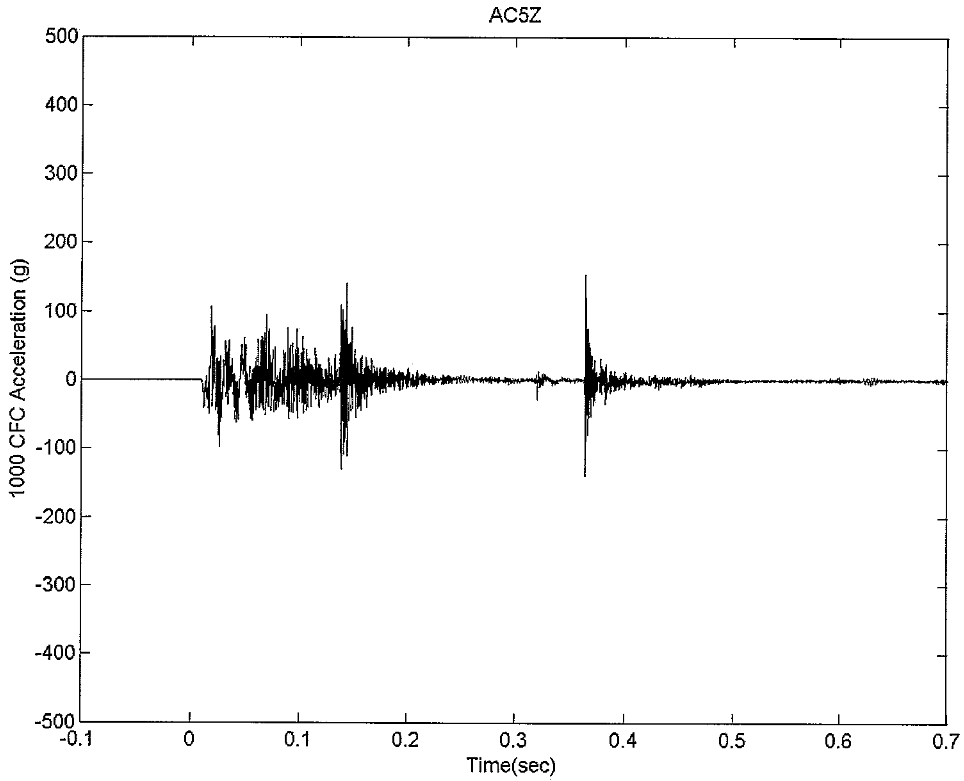

AC4X
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

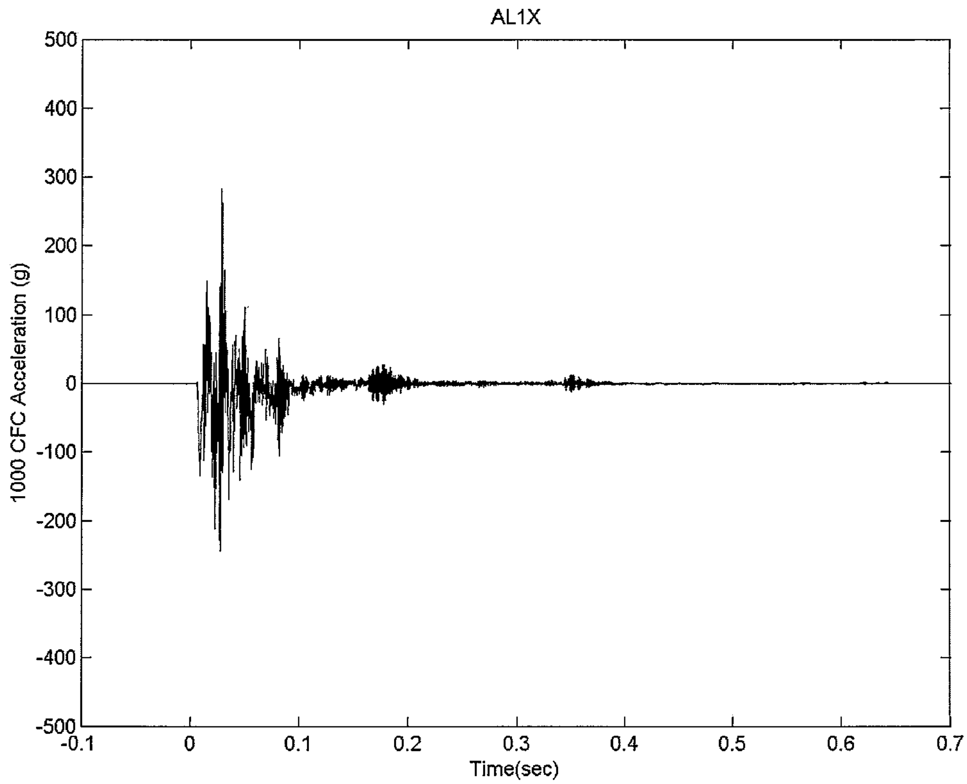

AC4Y
20
15
10
5
0
-5
-10
-15
-20
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

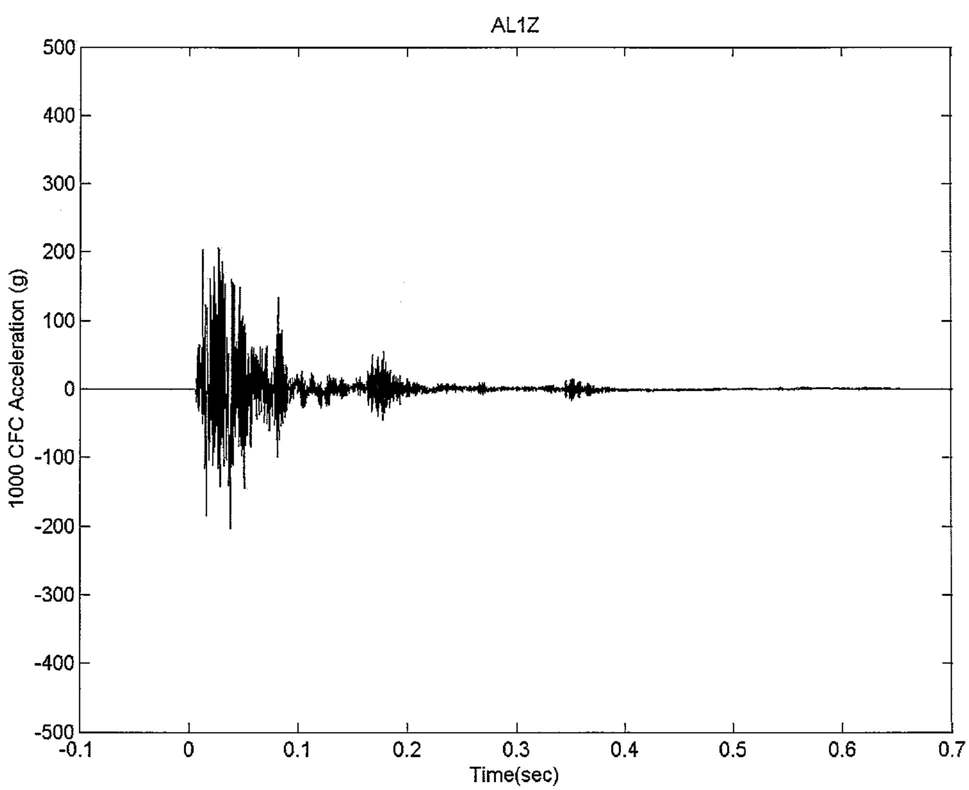

AC4Z
100
80
60
40
20
0
-20
-40
-60
-80
-100
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

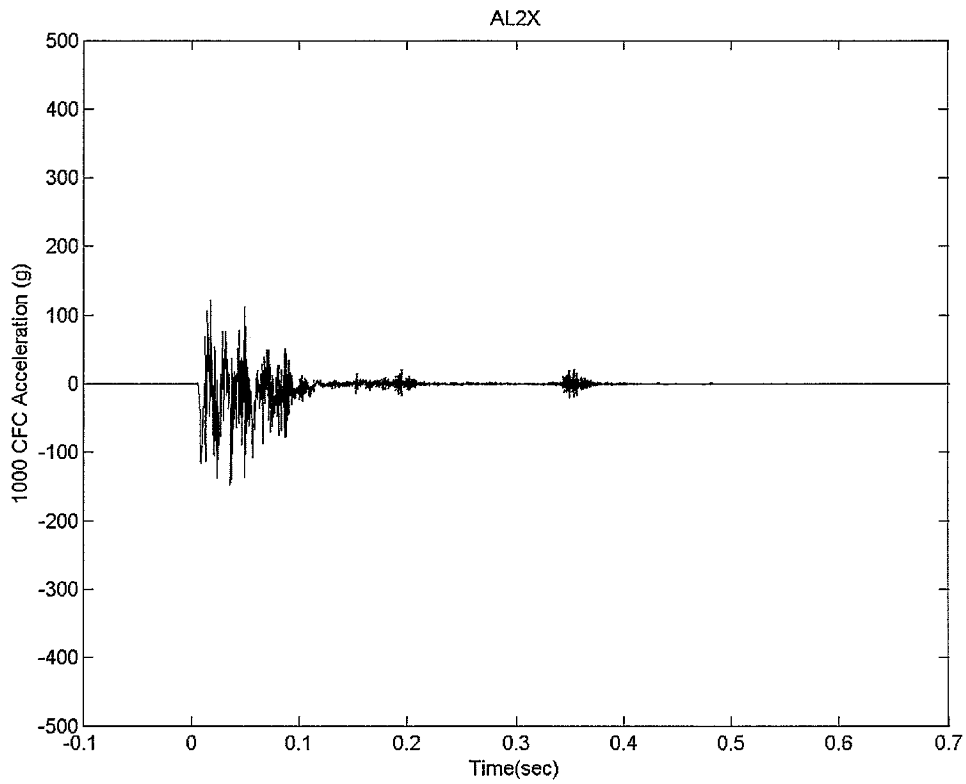

AC5X
500
400
300
200
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

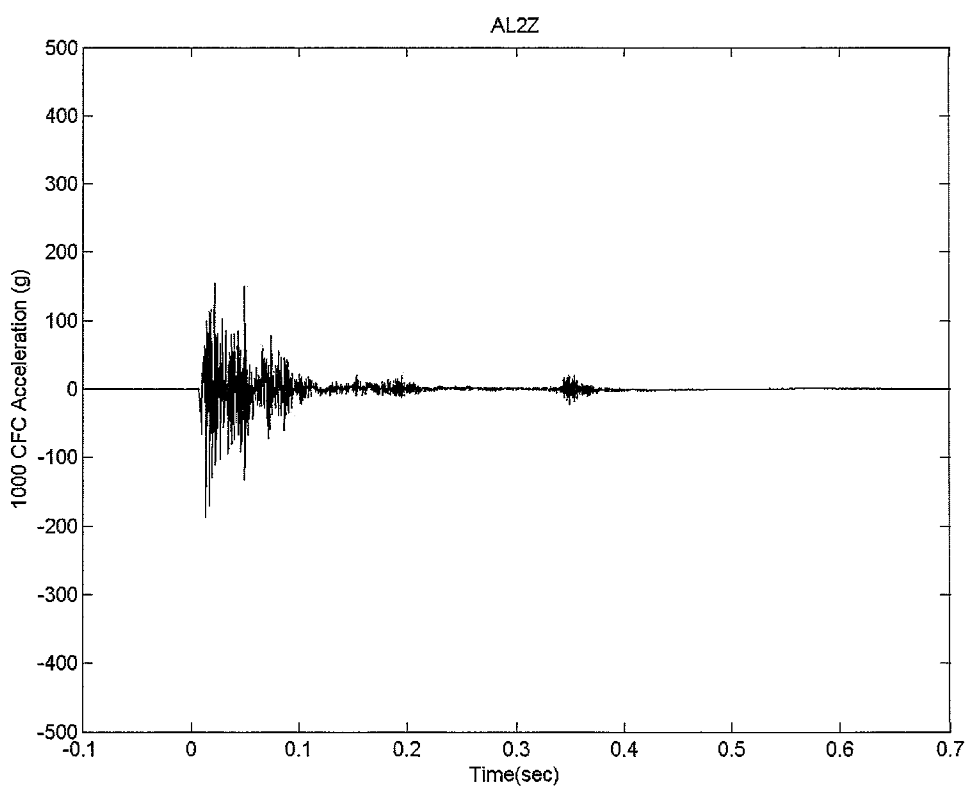

AC5Y
500
400
300
200
100
0
-100
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

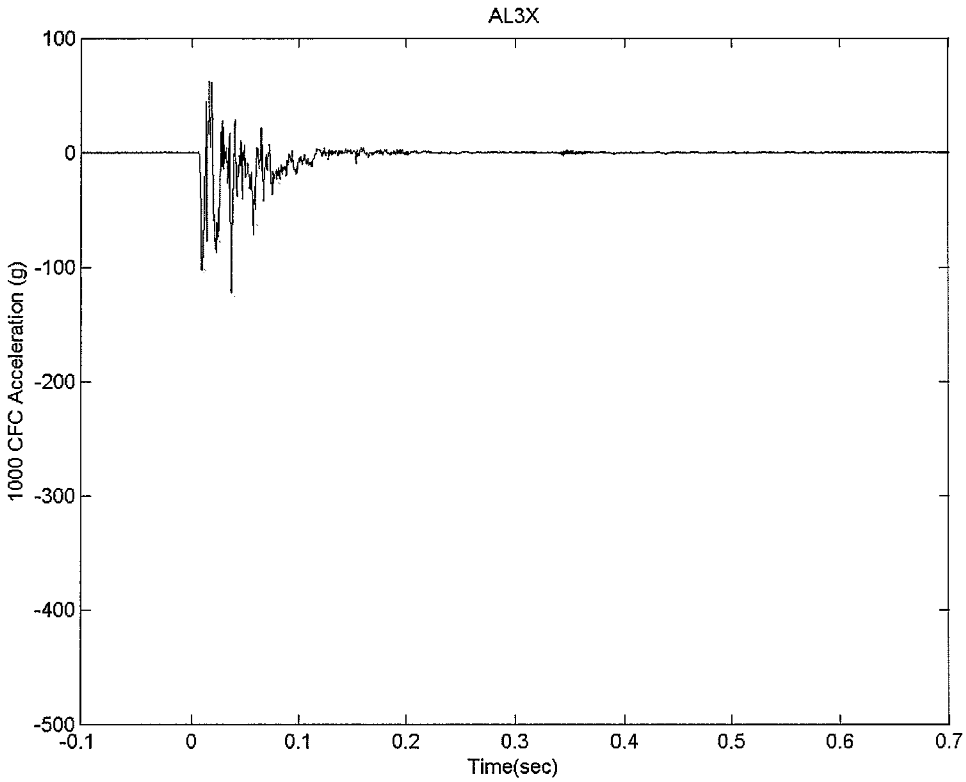

AC5Z
1000 CFC Acceleration (g)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

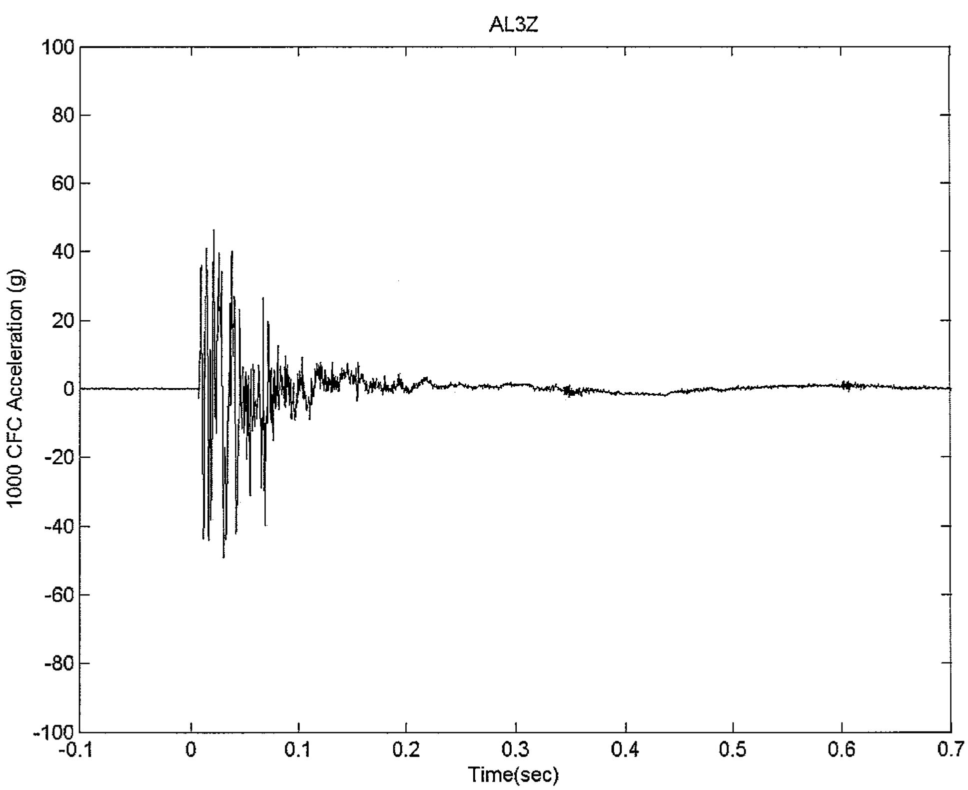

AL1X
1000 CFC Acceleration (g)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

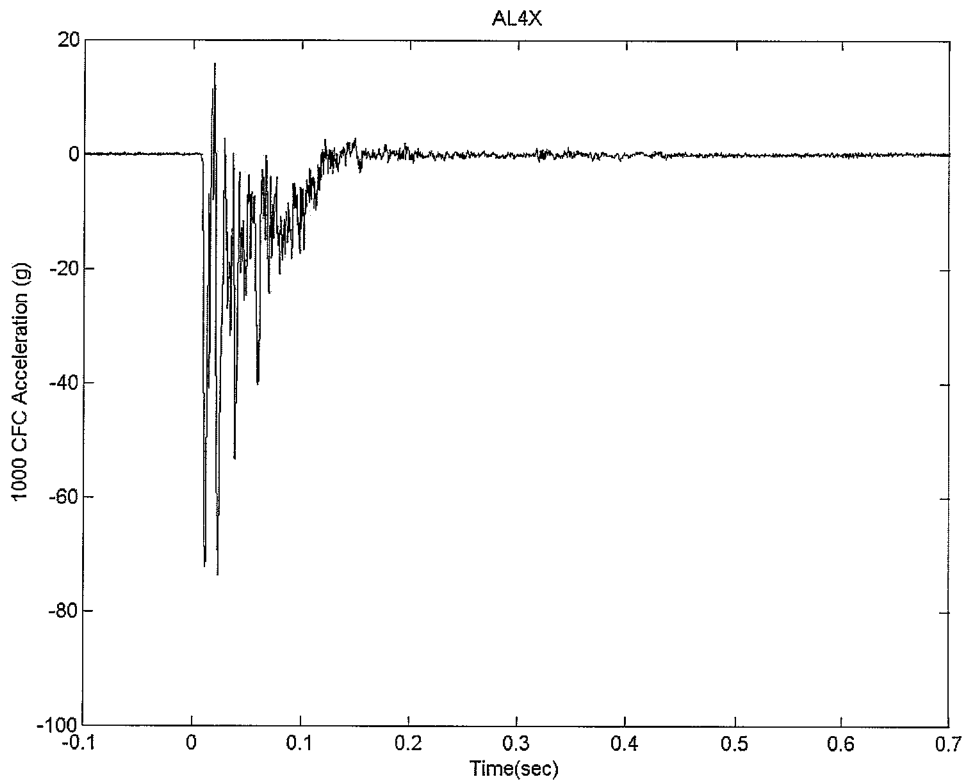

AL1Z
1000 CFC Acceleration (g)
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

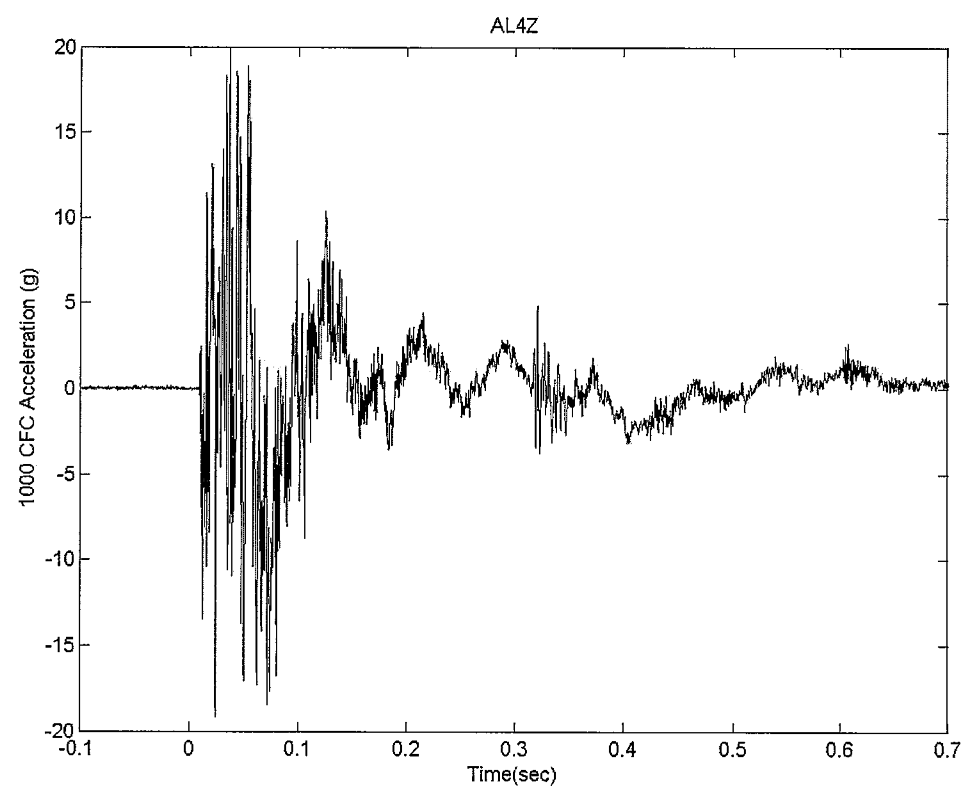

AL2X
1000 CFC Acceleration (g)
Time(sec)

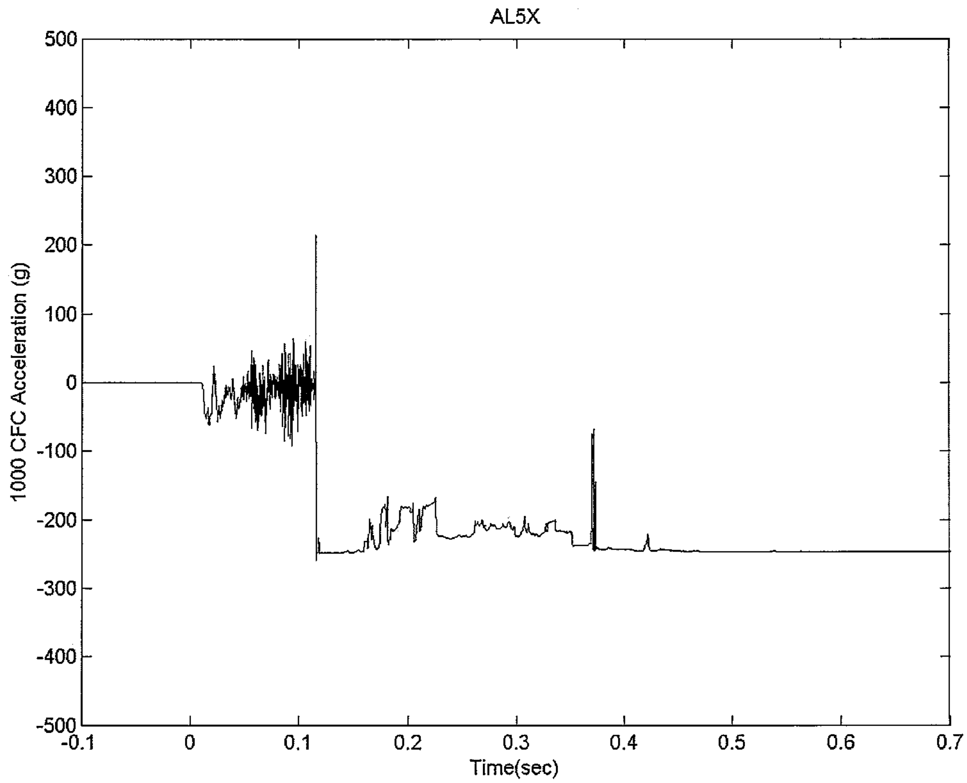

AL2Z
1000 CFC Acceleration (g)
Time(sec)

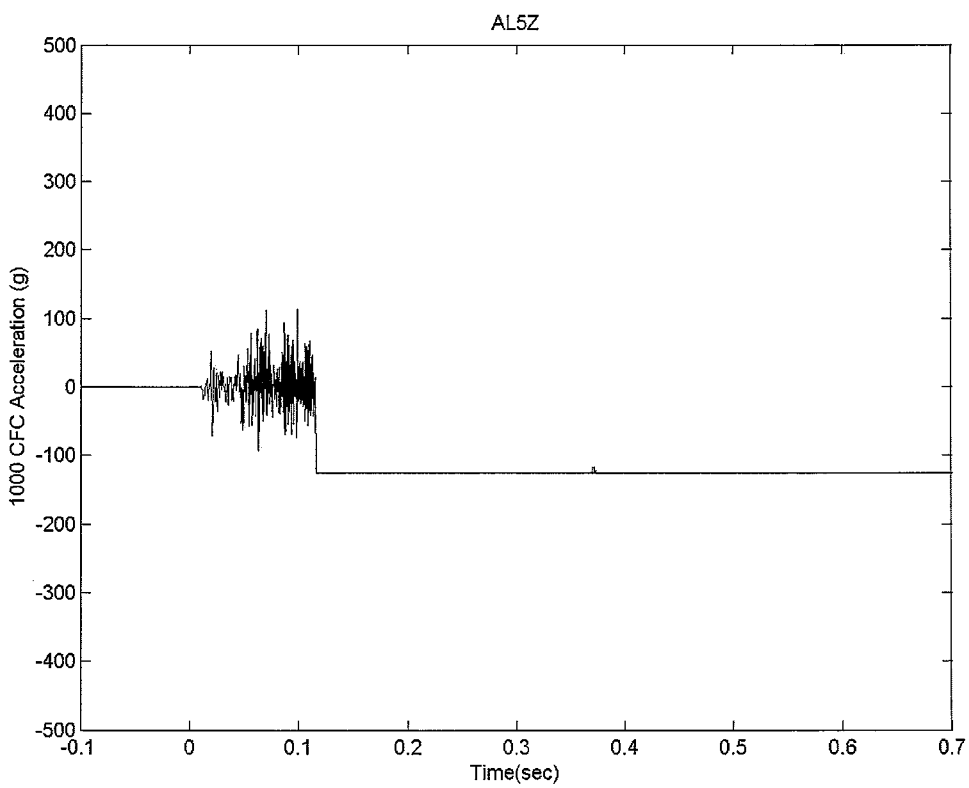

AL3X
1000 CFC Acceleration (g)
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

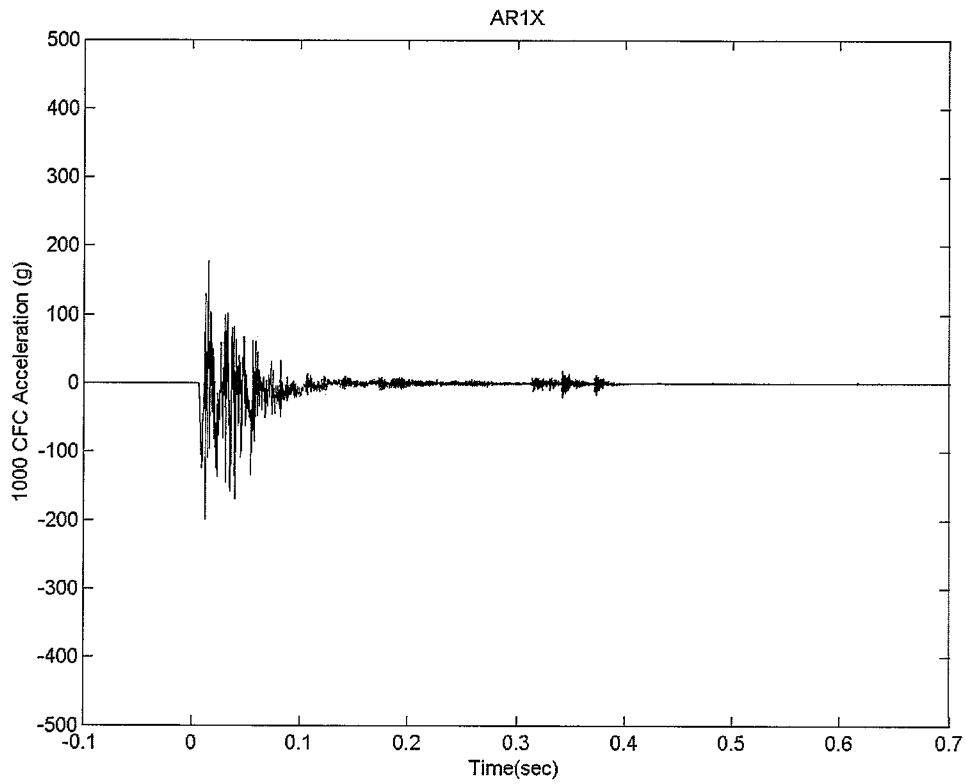

AL3Z
1000 CFC Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

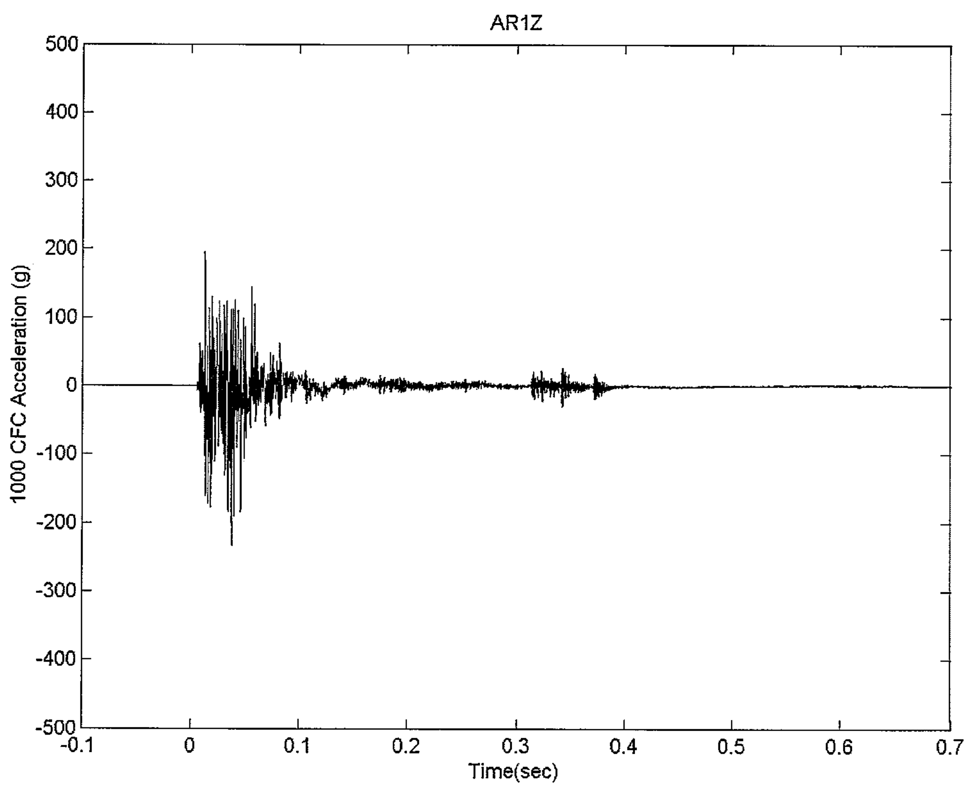

AL4X
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
1000 CFC Acceleration (g)

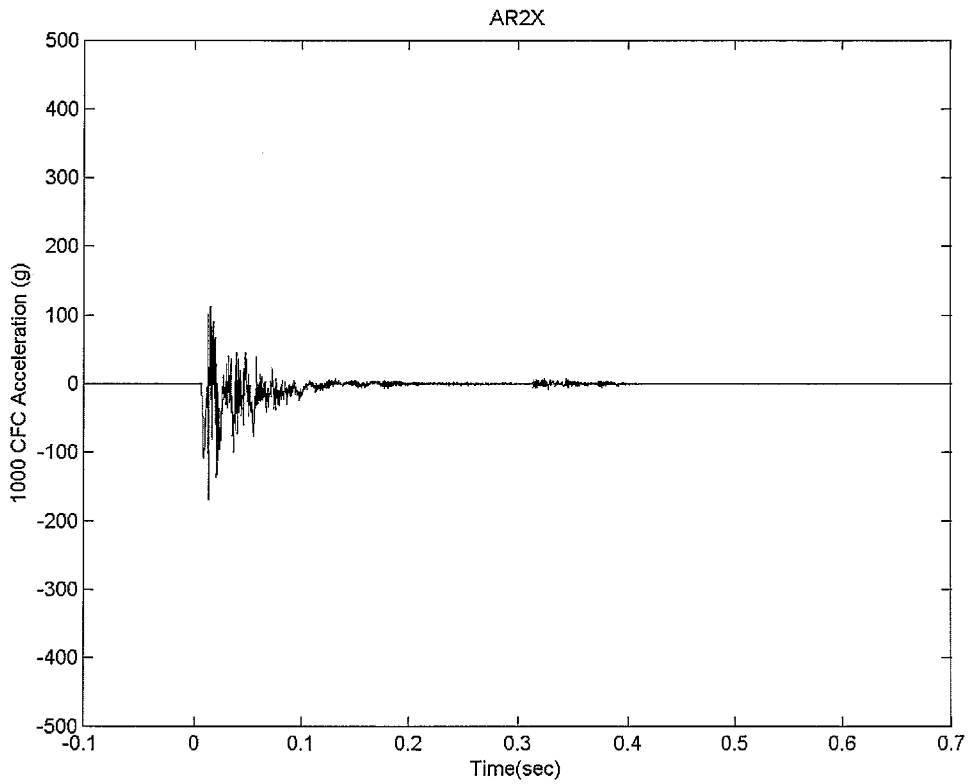

AL4Z
20
15
10
5
0
-5
-10
-15
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
1000 CFC Acceleration (g)

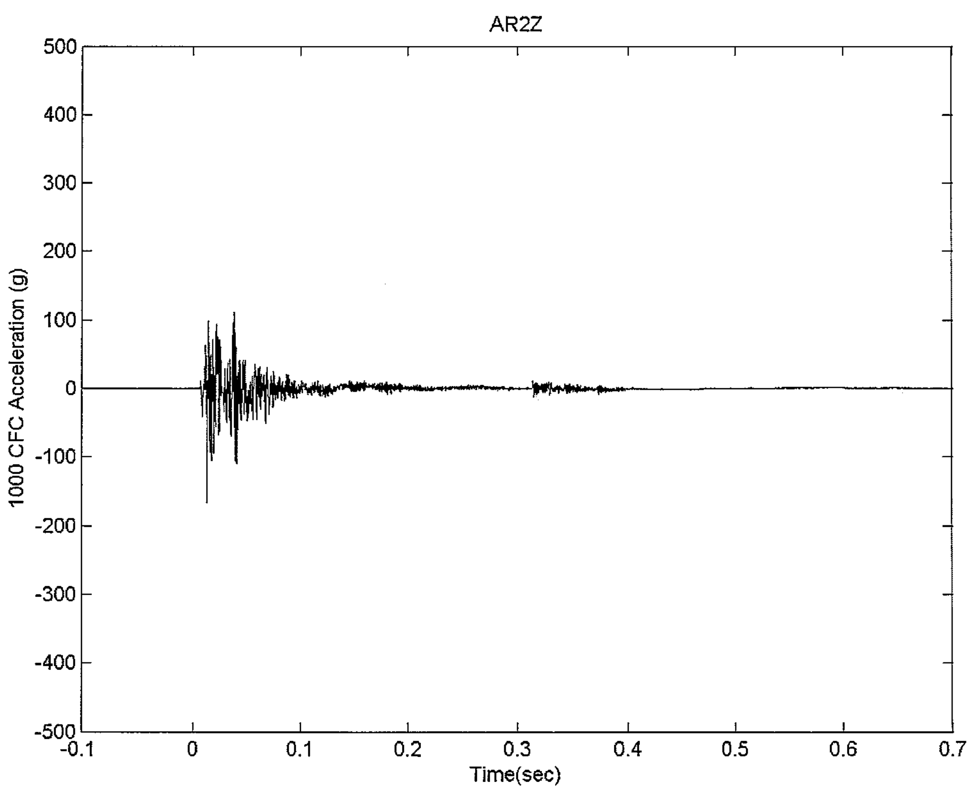

AL5X
500
400
300
200
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

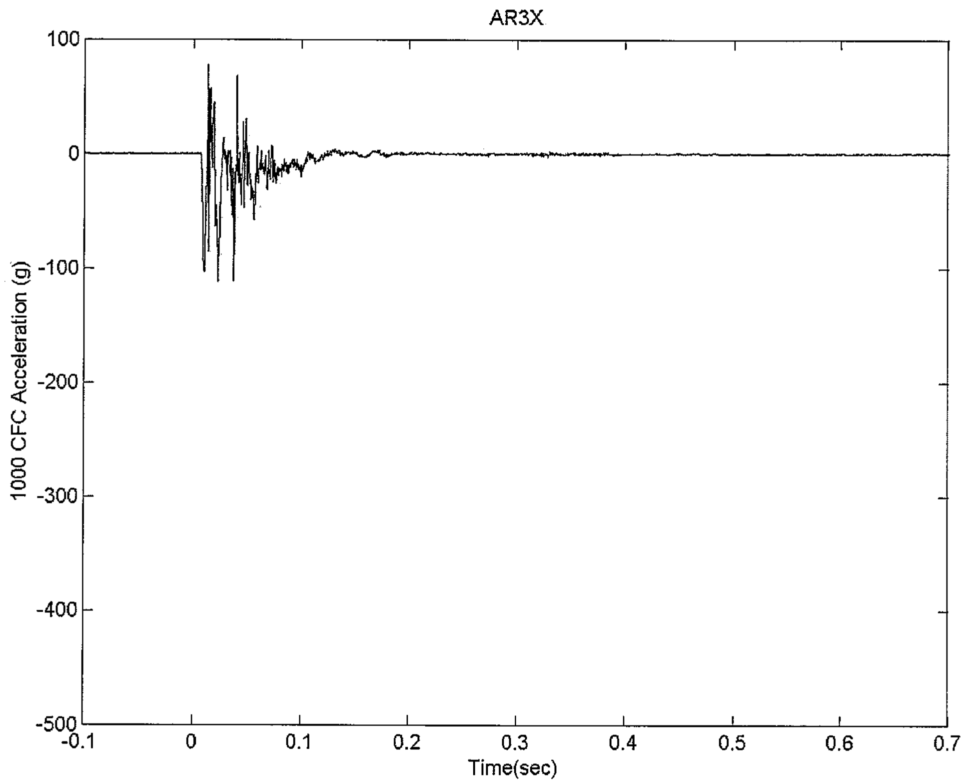

AL5Z
500
400
300
200
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AR1X
500
400
300
200
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

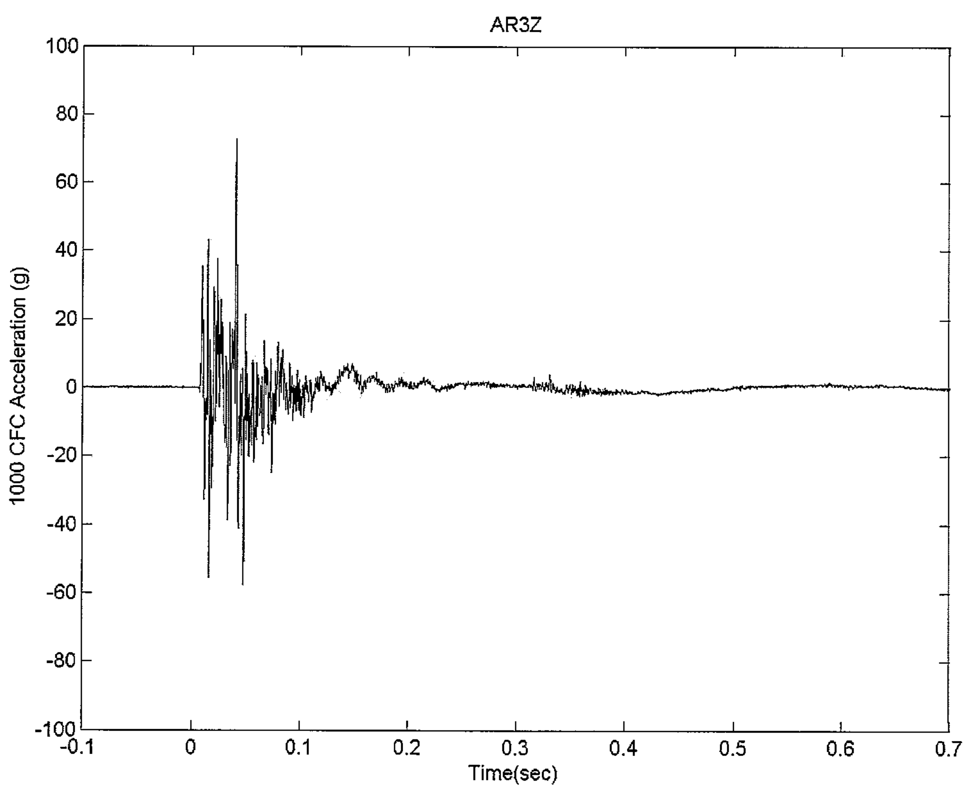

AR1Z
500
400
300
200
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AR2X
1000 CFC Acceleration (g)
Time(sec)

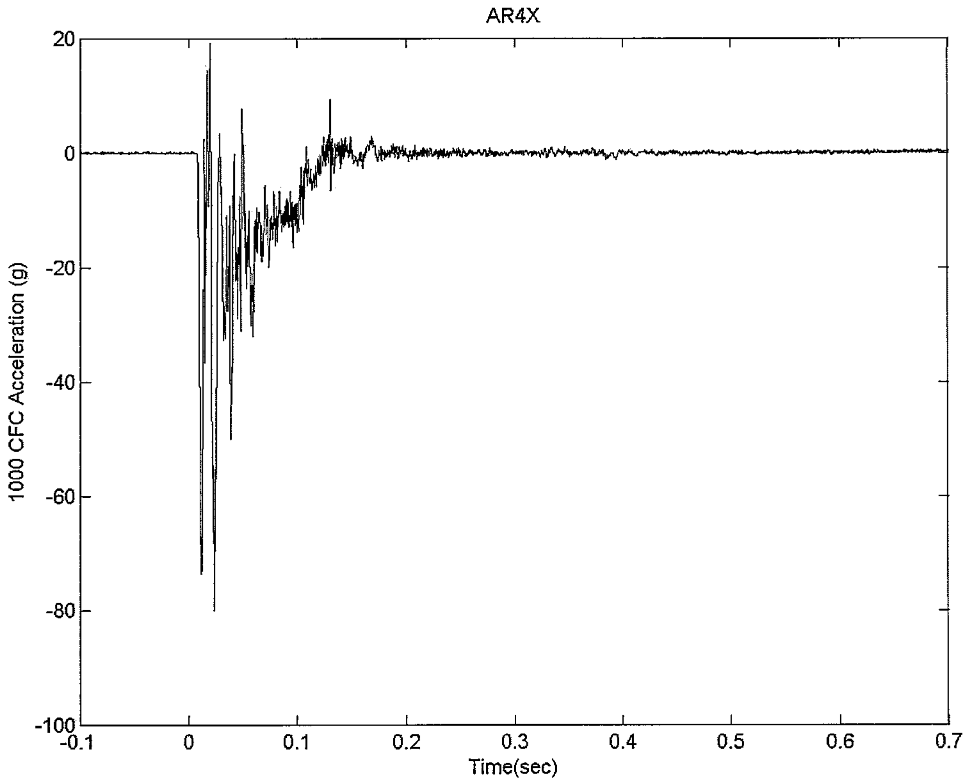

AR2Z
1000 CFC Acceleration (g)
Time(sec)

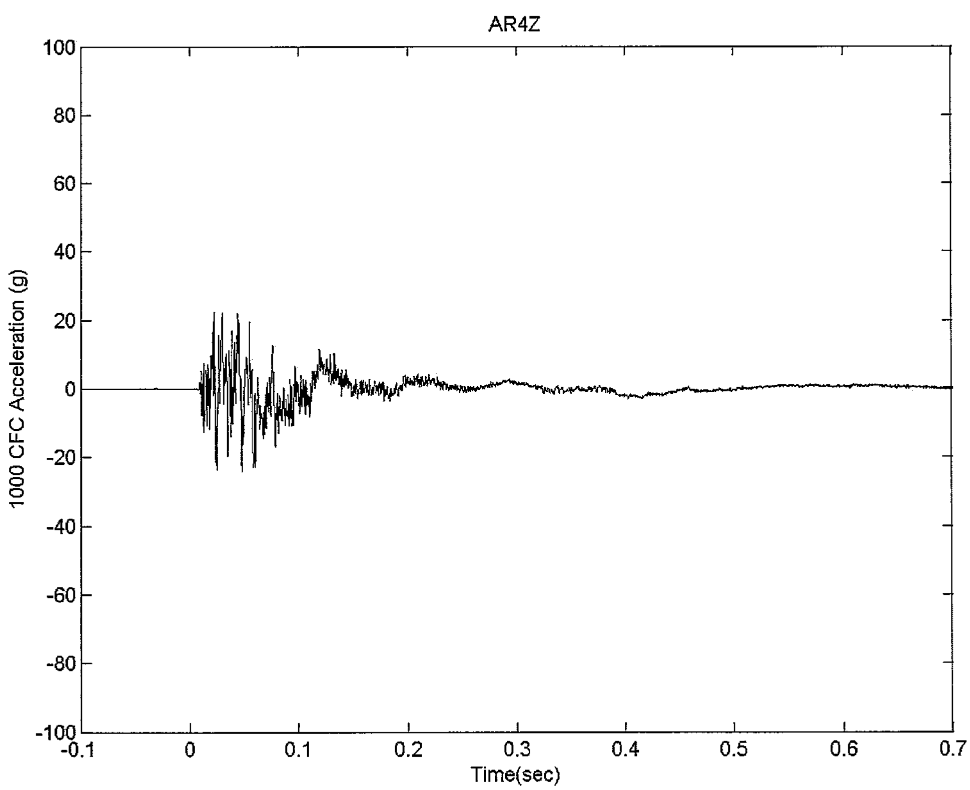


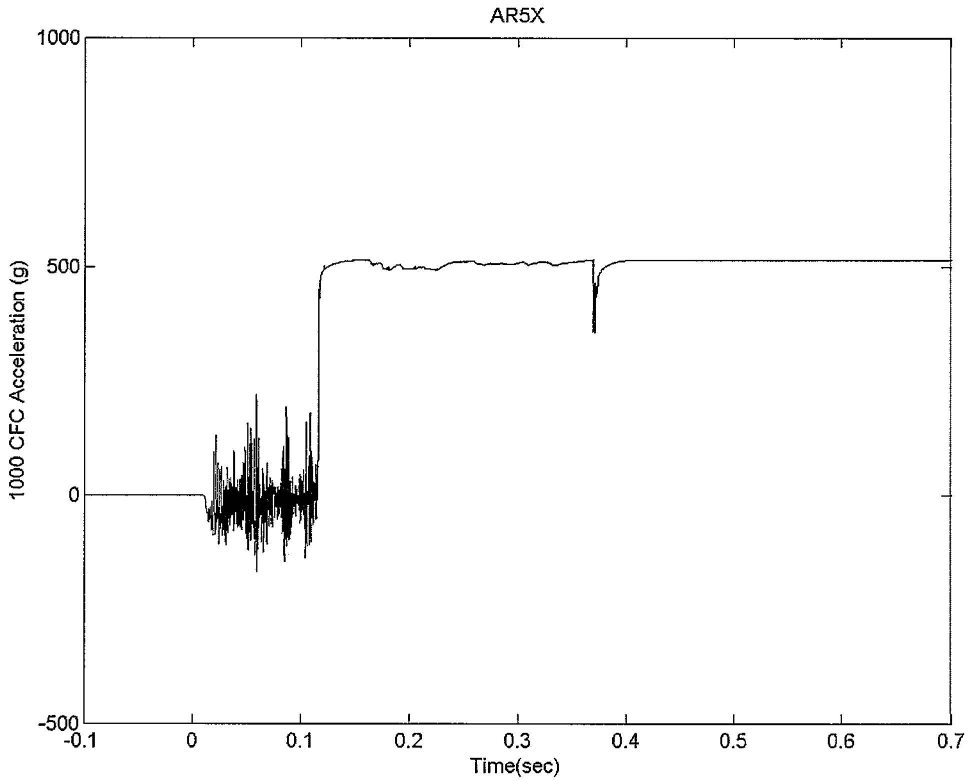
AR3X
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)



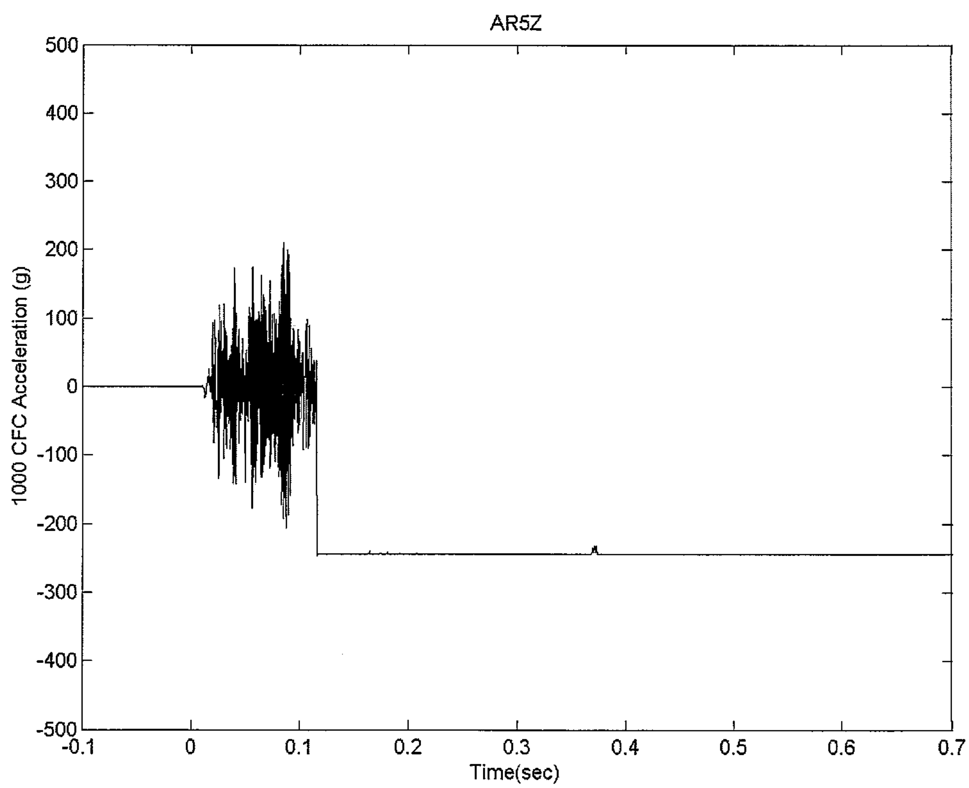
AR3Z
100
80
60
40
20
0
-20
-40
-60
-80
-100
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


AR4X
1000 CFC Acceleration (g)
Time(sec)
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

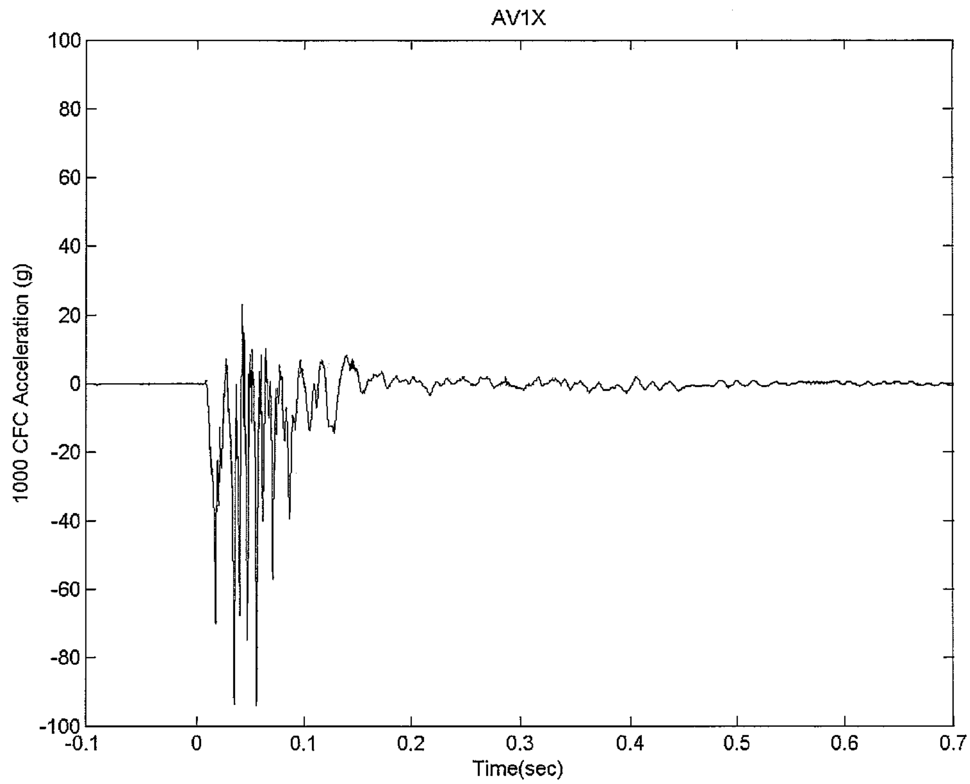

AR4Z
1000 CFC Acceleration (g)
Time(sec)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

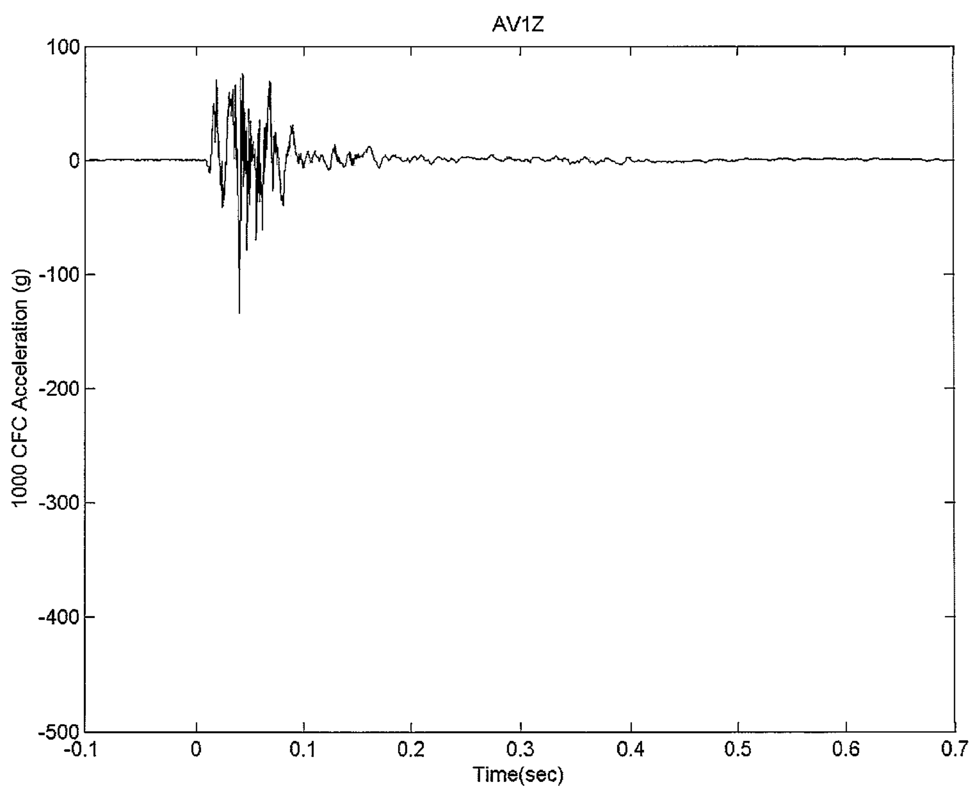


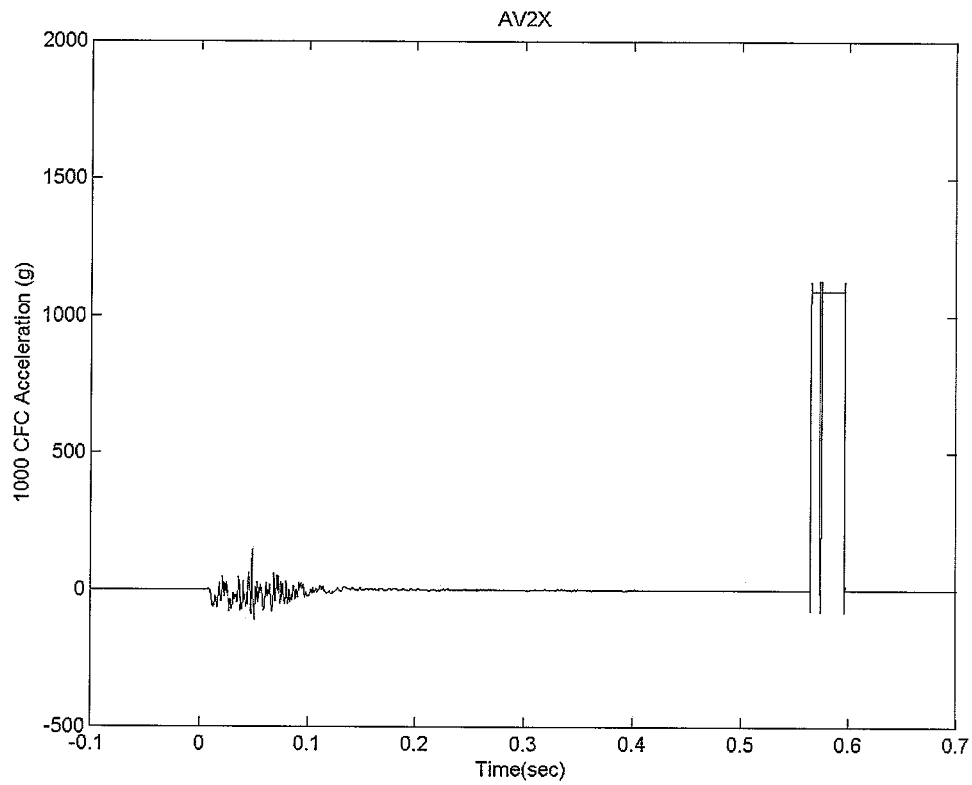
AR5X
1000
500
0
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
1000 CFC Acceleration (g)

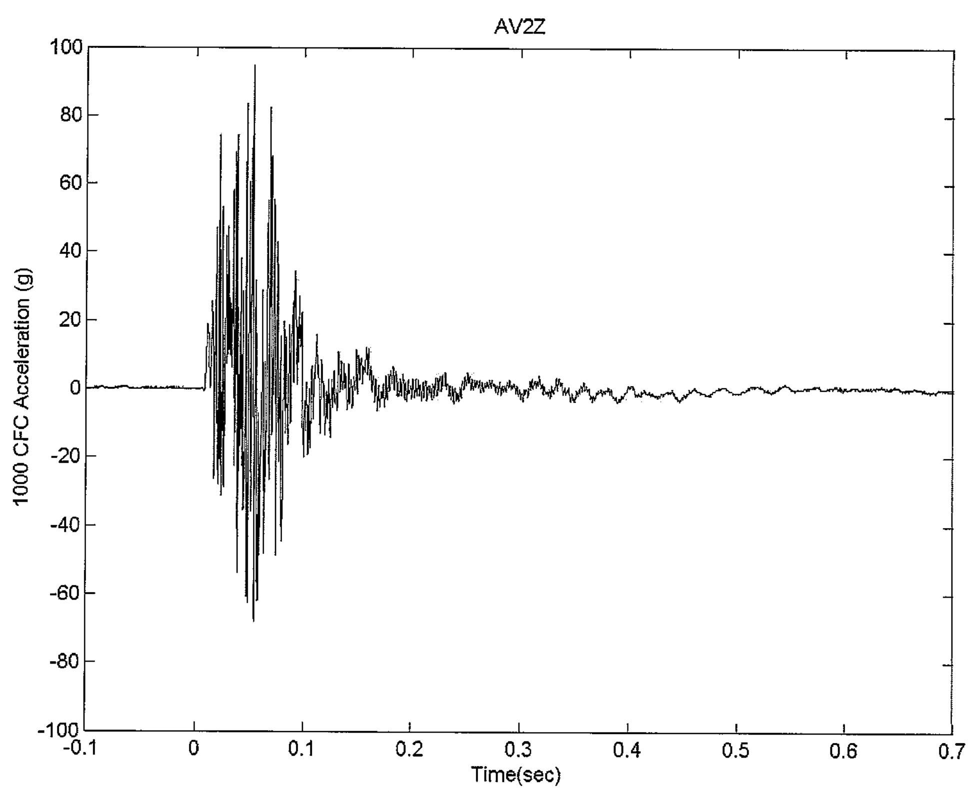


AR5Z
500
400
300
200
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
1000 CFC Acceleration (g)


AV1X
100
80
60
40
20
0
-20
-40
-60
-80
-100
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

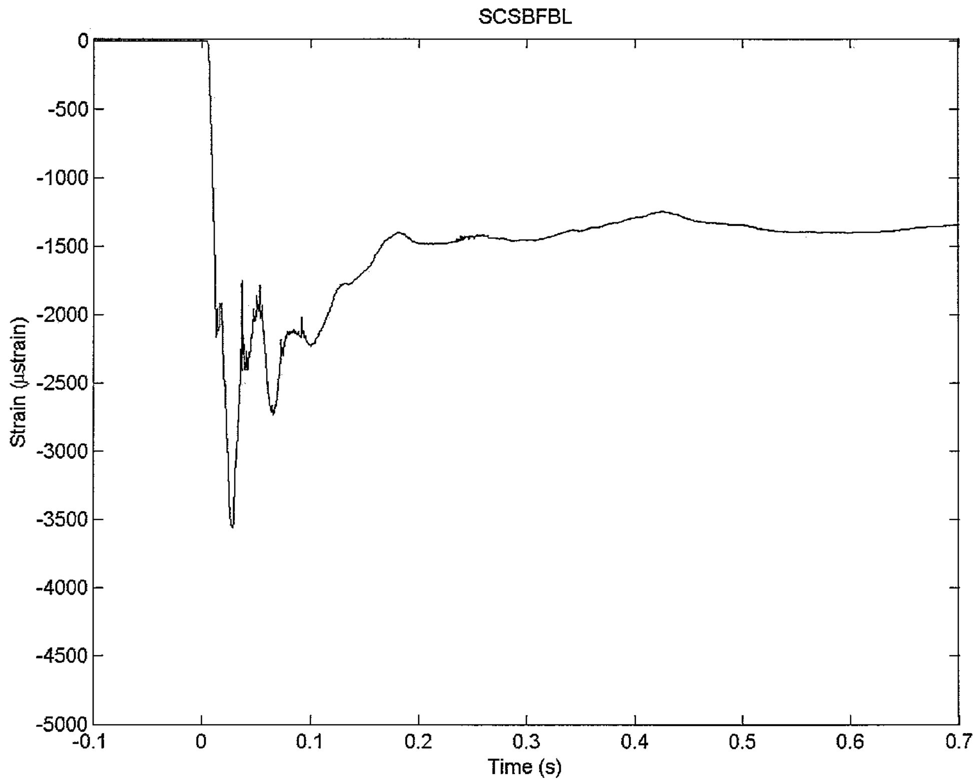

AV1Z
100
0
-100
-200
-300
-400
-500
1000 CFC Acceleration (g)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

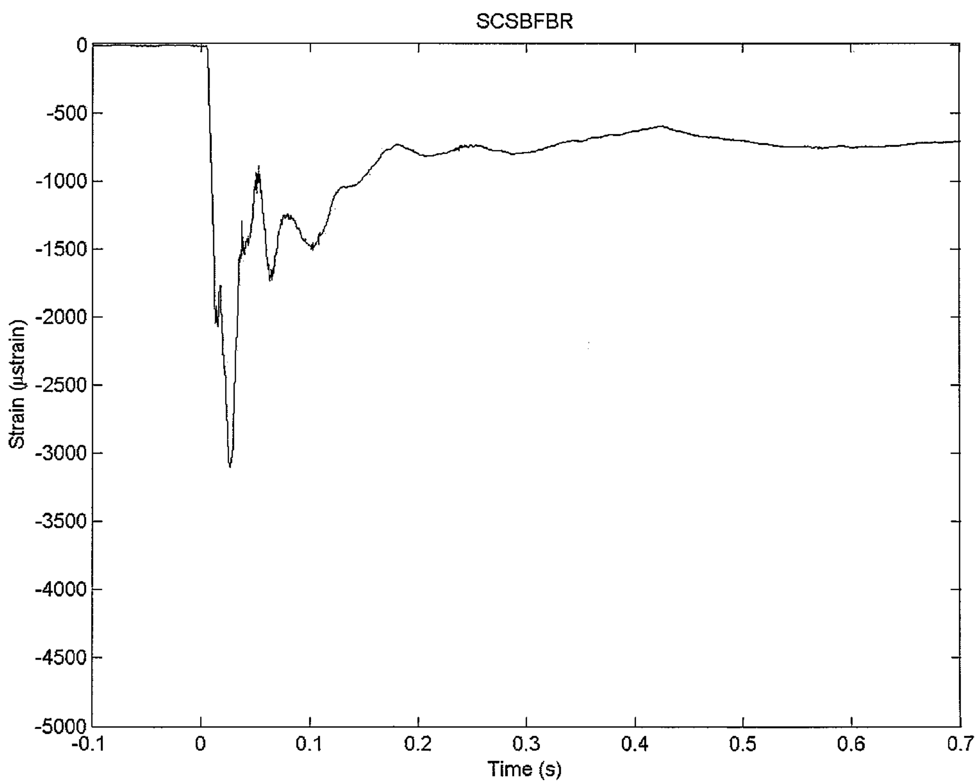

AV2X
1000 CFC Acceleration (g)
2000
1500
1000
500
0
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

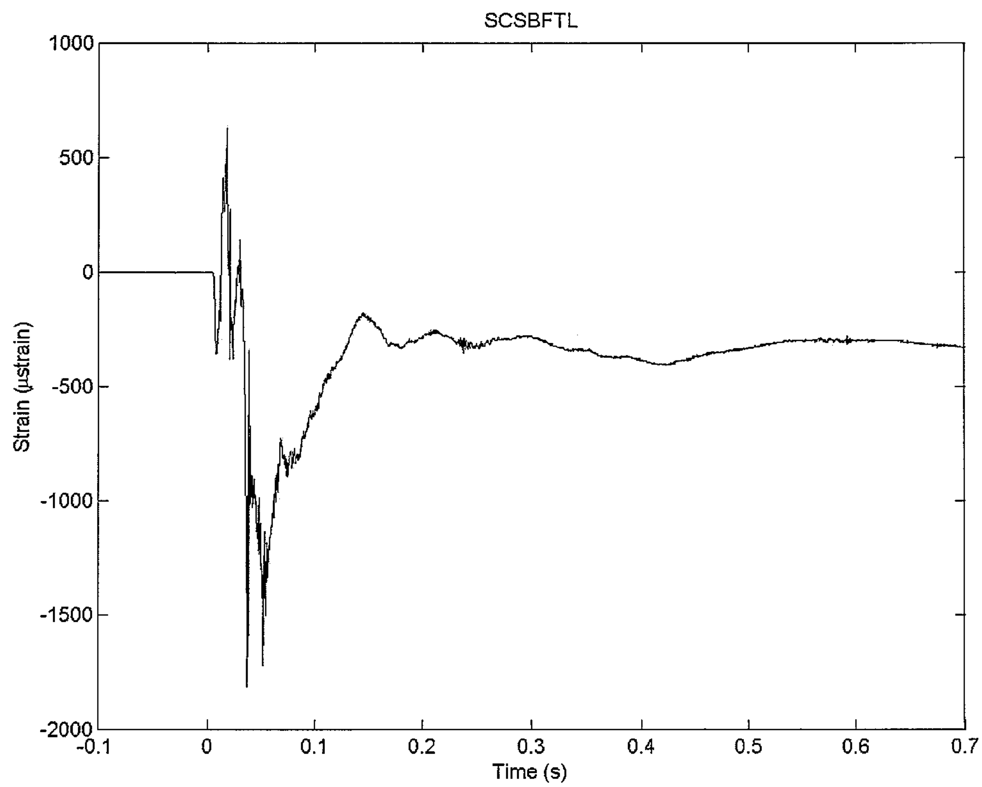

AV2Z
1000 CFC Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

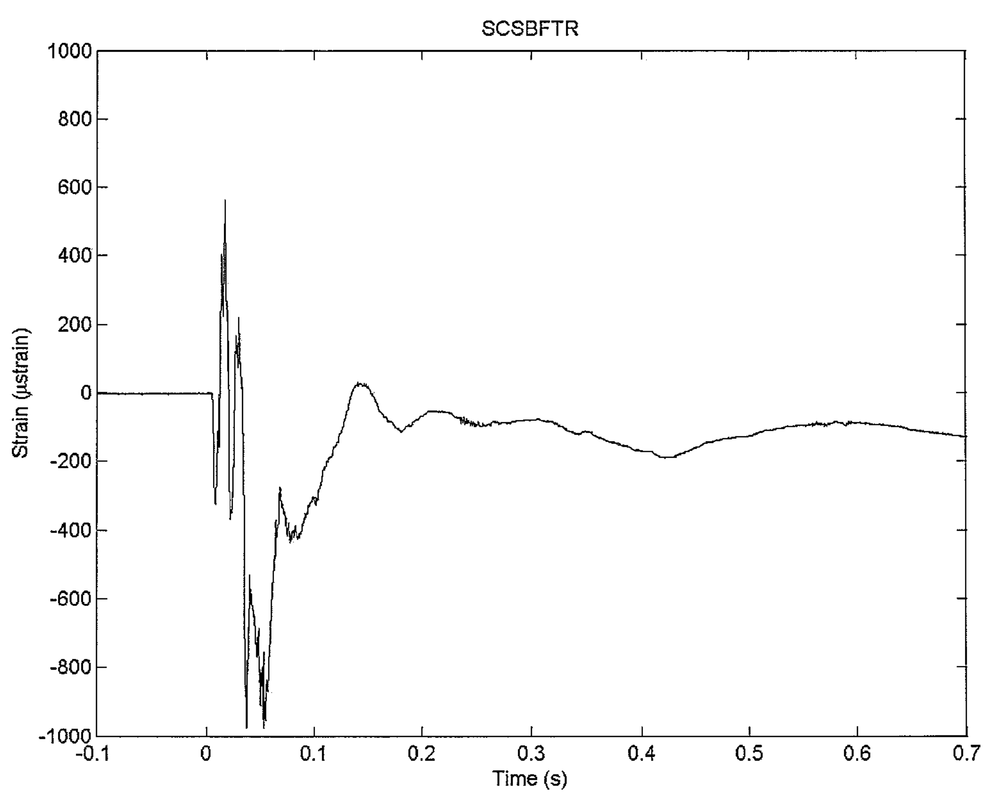
APPENDIX C.

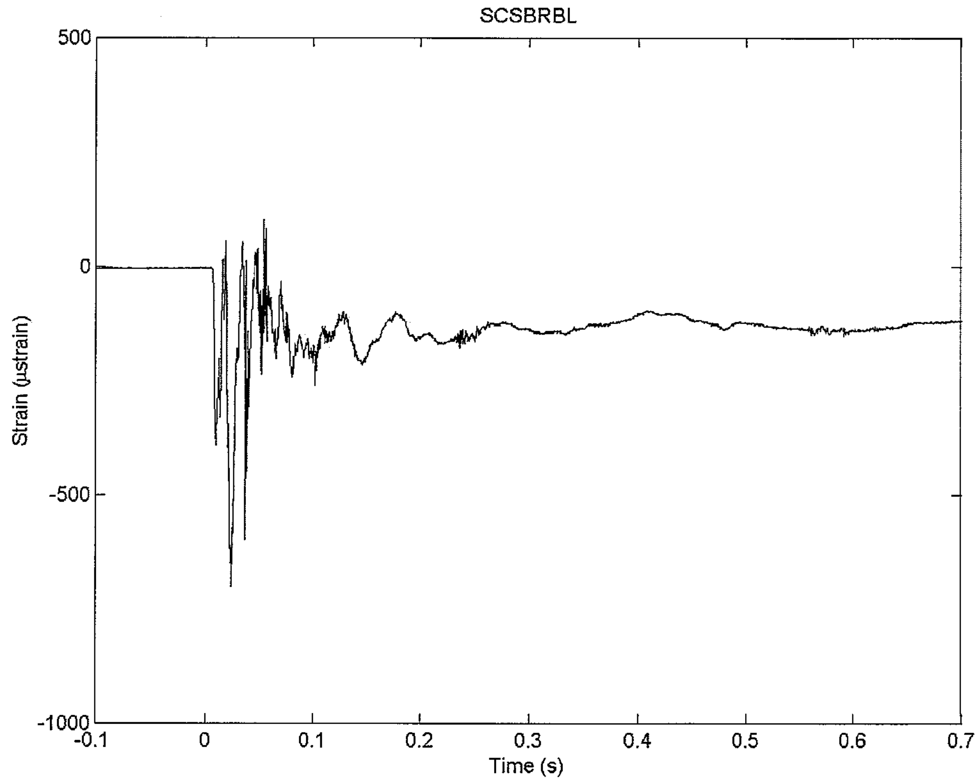
Strain Plots

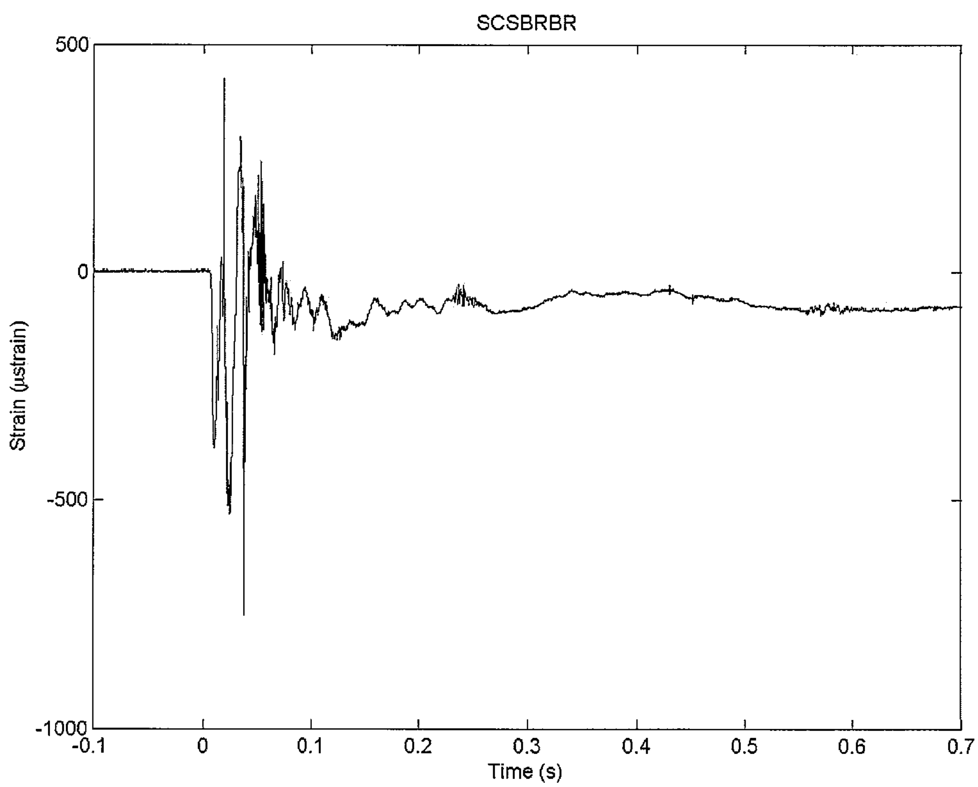

SCSBFBL
Strain (μstrain)
Time (s)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

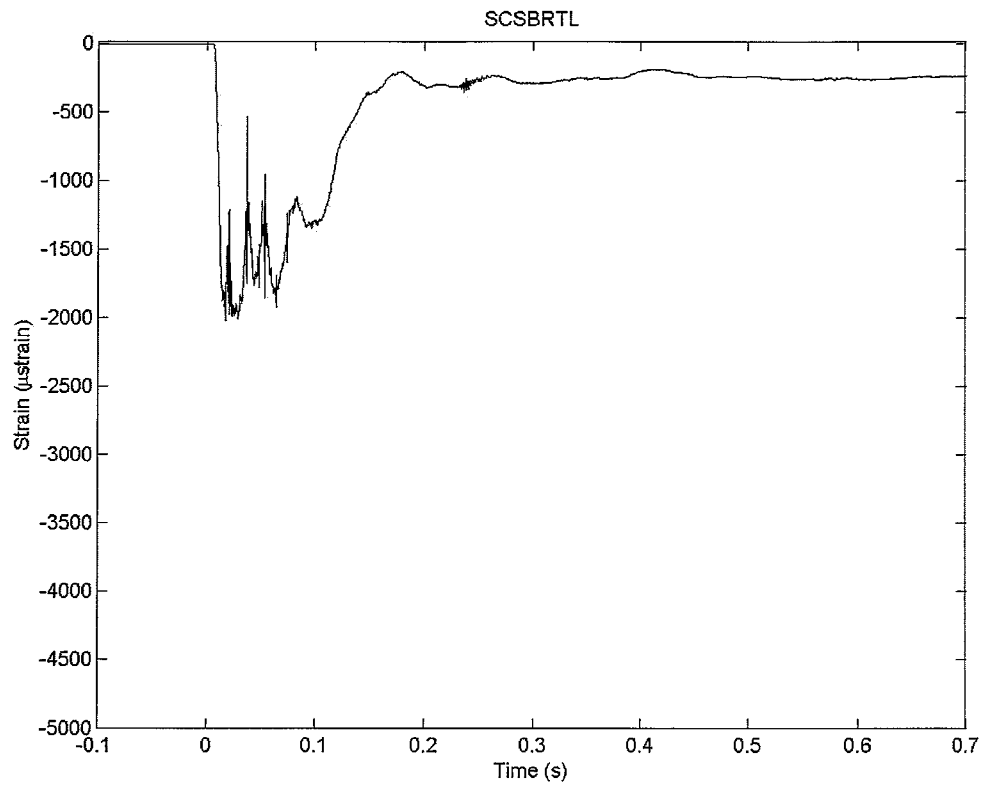

SCSBFBR
Strain (μstrain)
Time (s)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

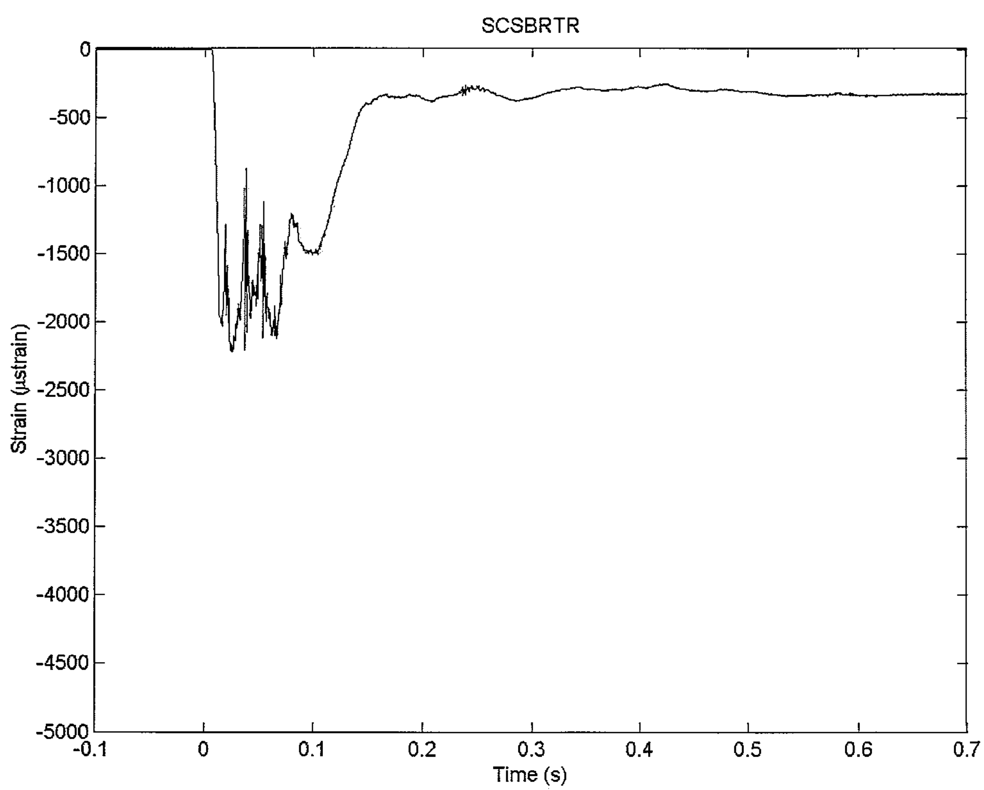

SCSBFTL
Strain (µstrain)
Time (s)
1000
500
0
-500
-1000
-1500
-2000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

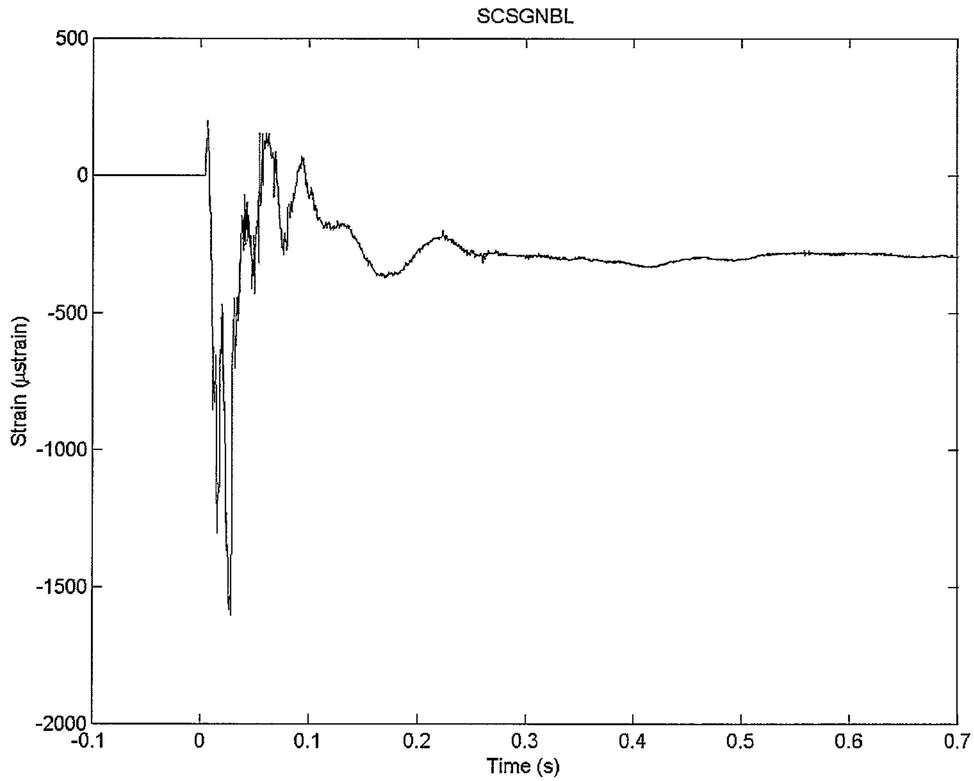

SCSBFTR
Strain (µstrain)
Time (s)
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

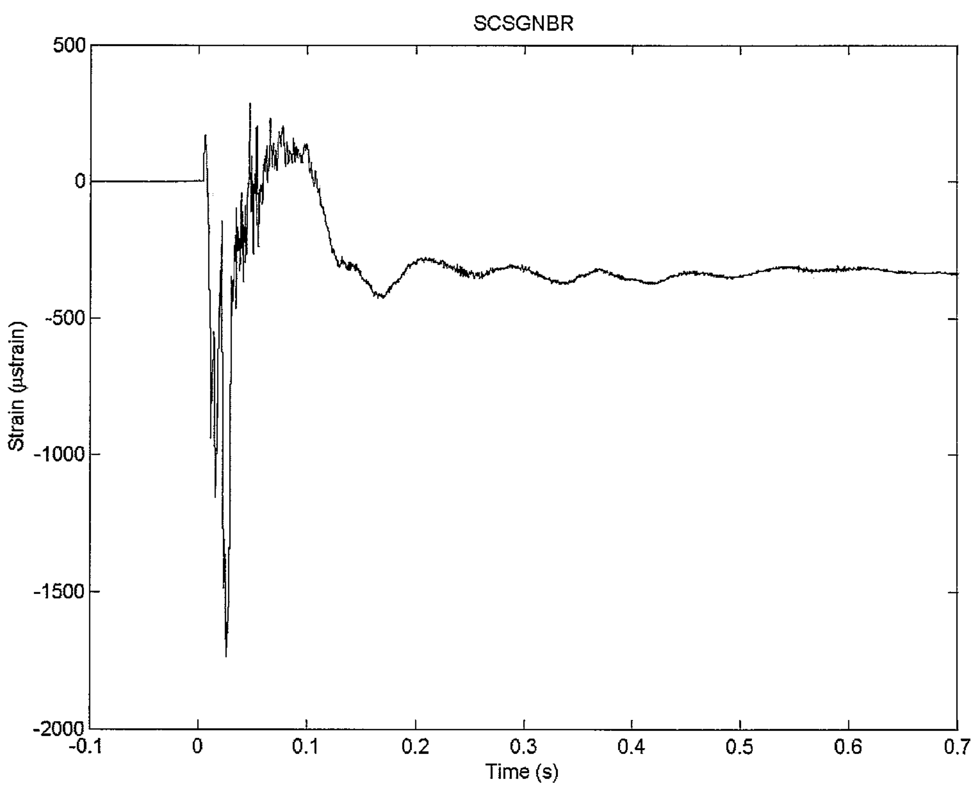

SCSBRBL
500
0
-500
-1000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

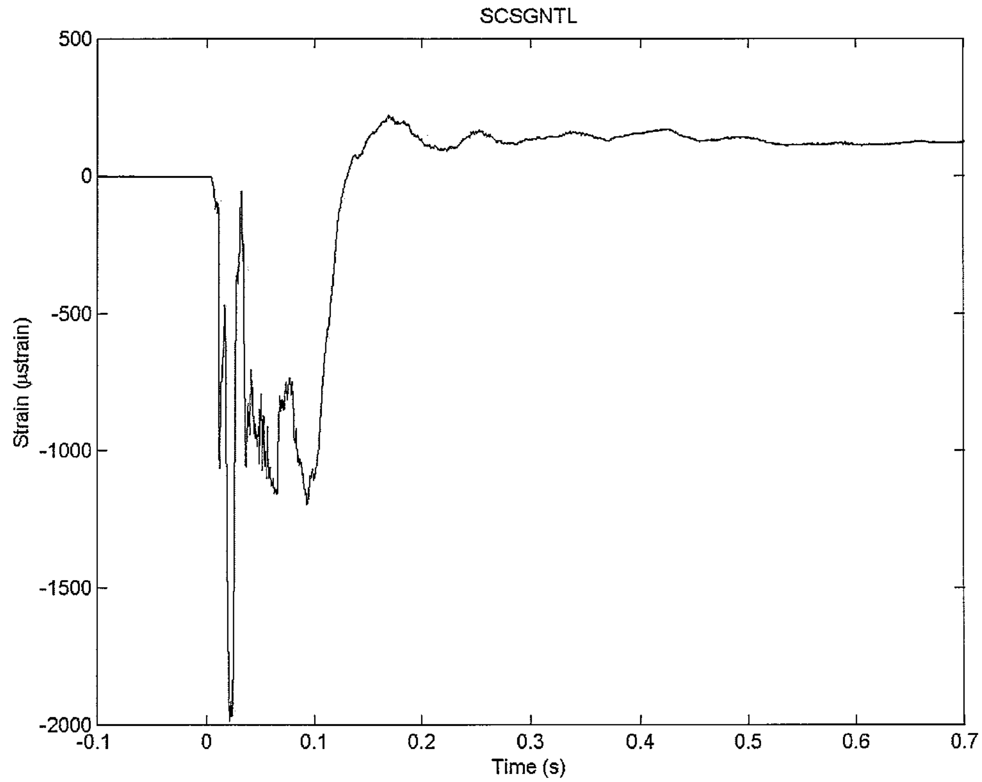

SCSBRBR
500
0
-500
-1000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

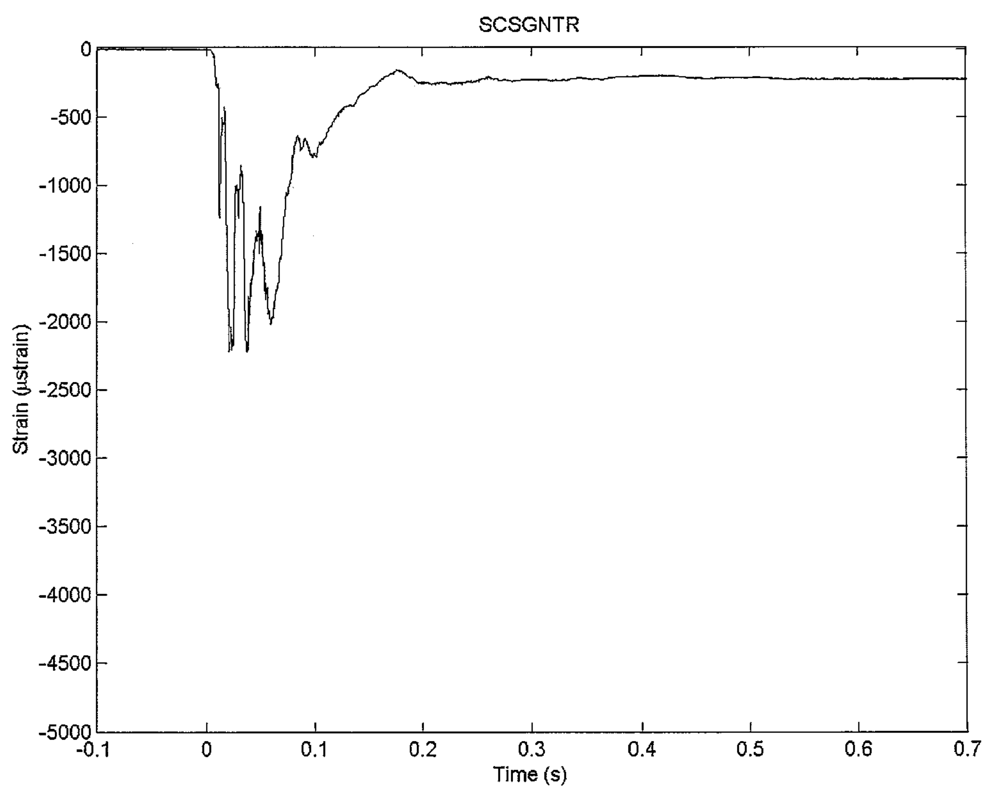

SCSBRTL
Strain (µstrain)
Time (s)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

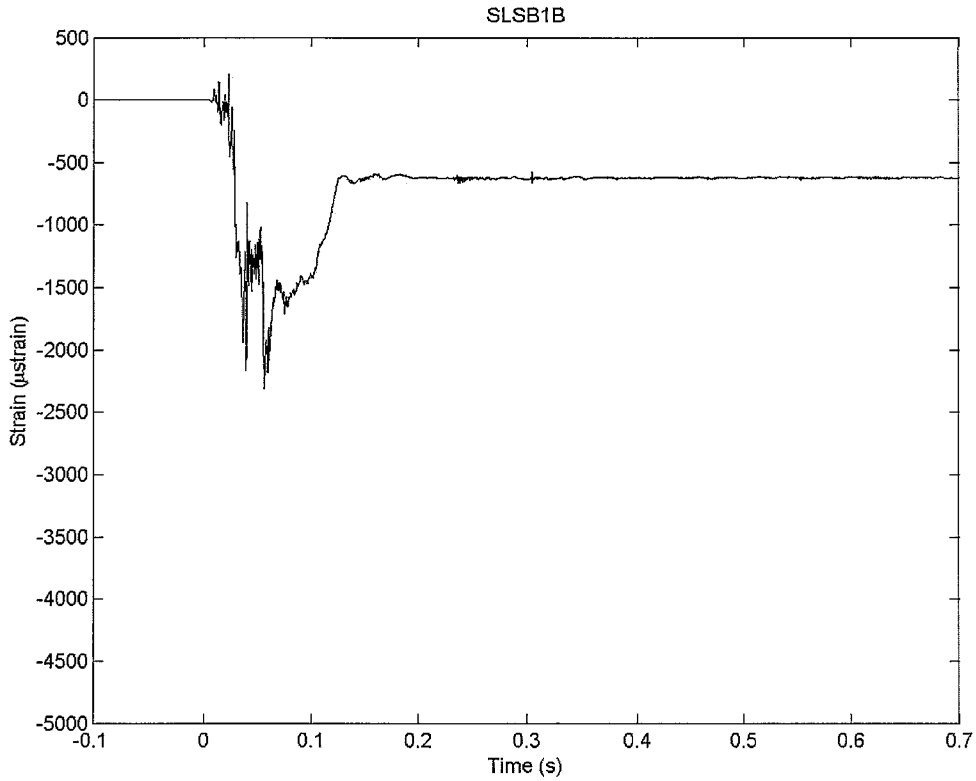

SCSBRTR
Strain (µstrain)
Time (s)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

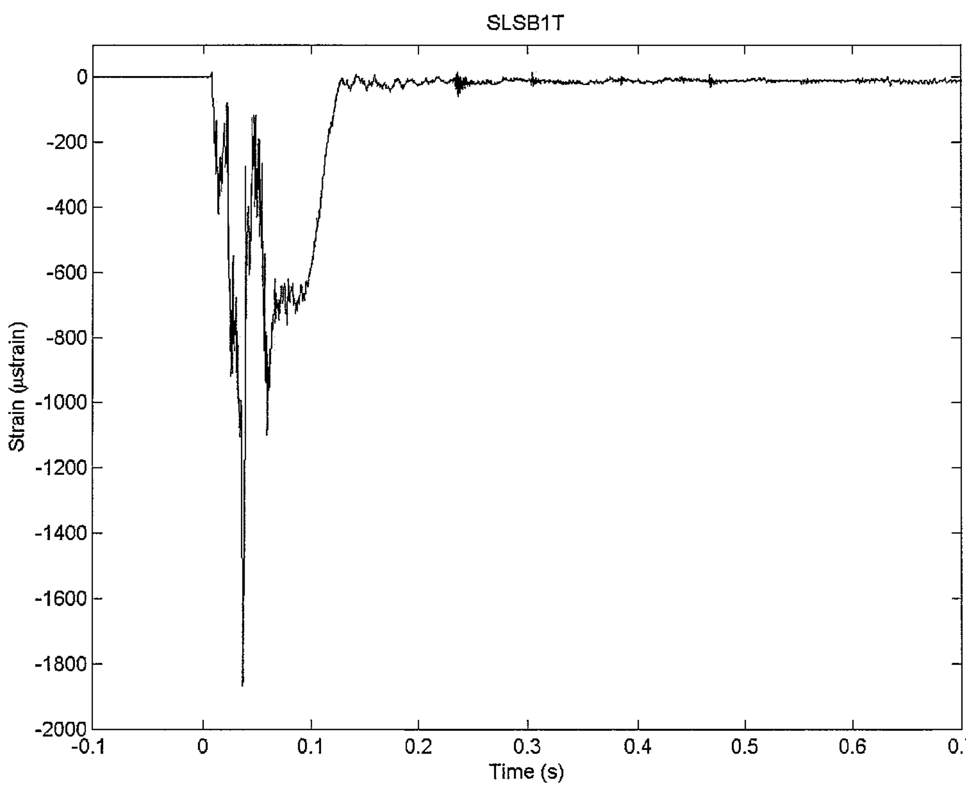

SCSGNBL
500
0
-500
-1000
-1500
-2000
Strain (μstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

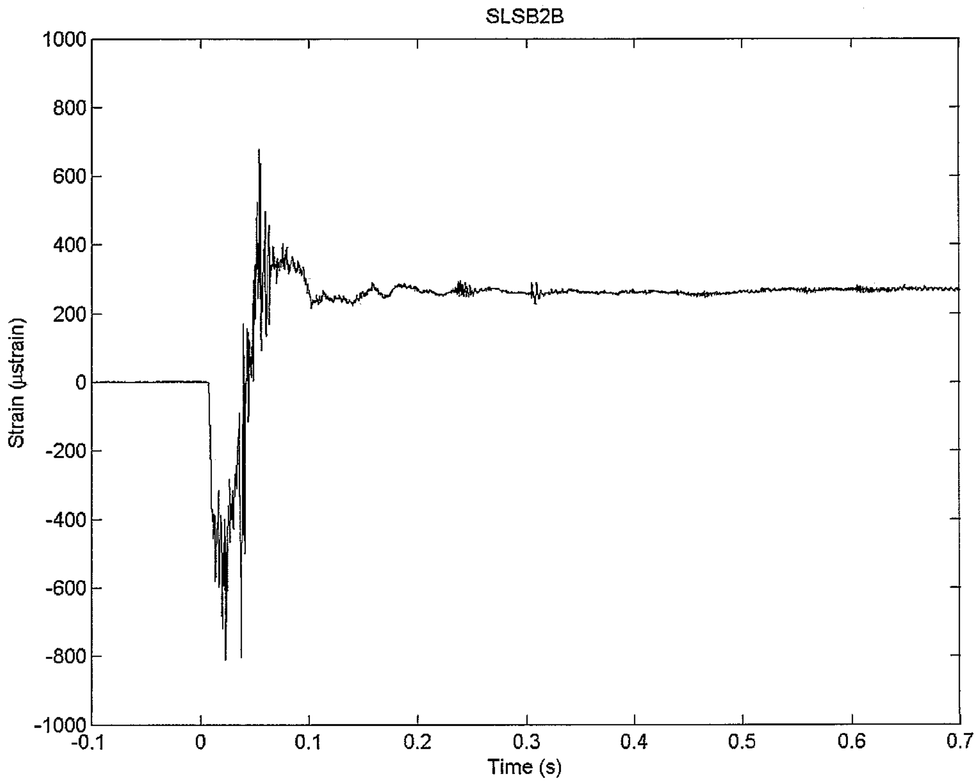

SCSGNBR
500
0
-500
-1000
-1500
-2000
Strain (μstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

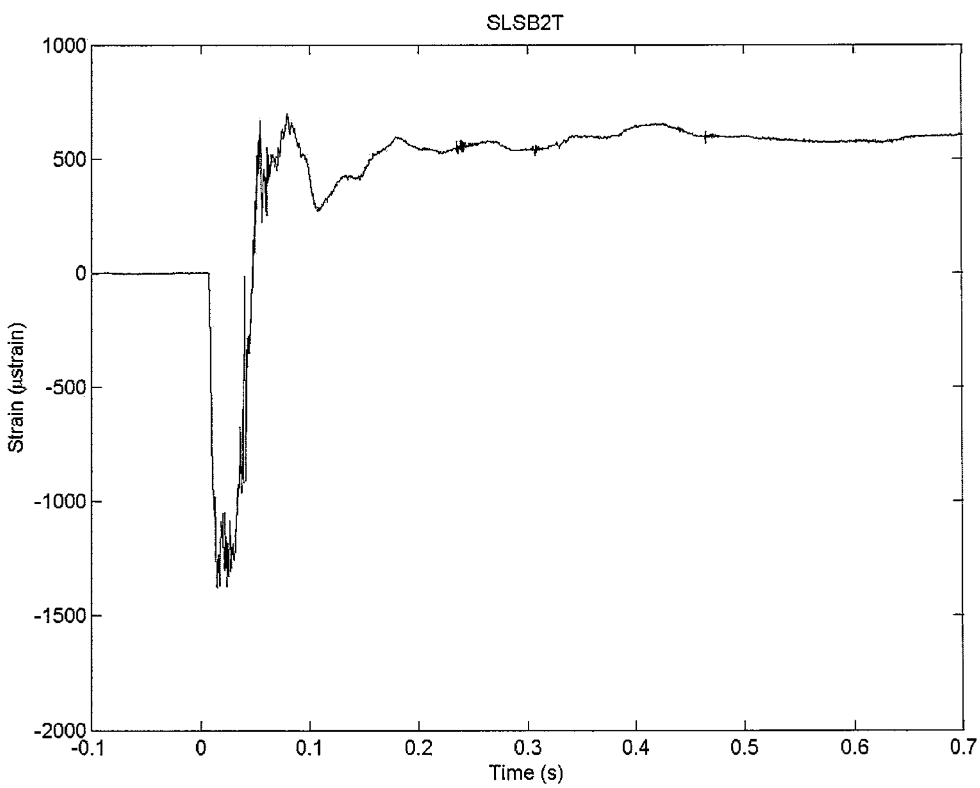

SCSGNTL
Strain (μstrain)
Time (s)
500
0
-500
-1000
-1500
-2000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

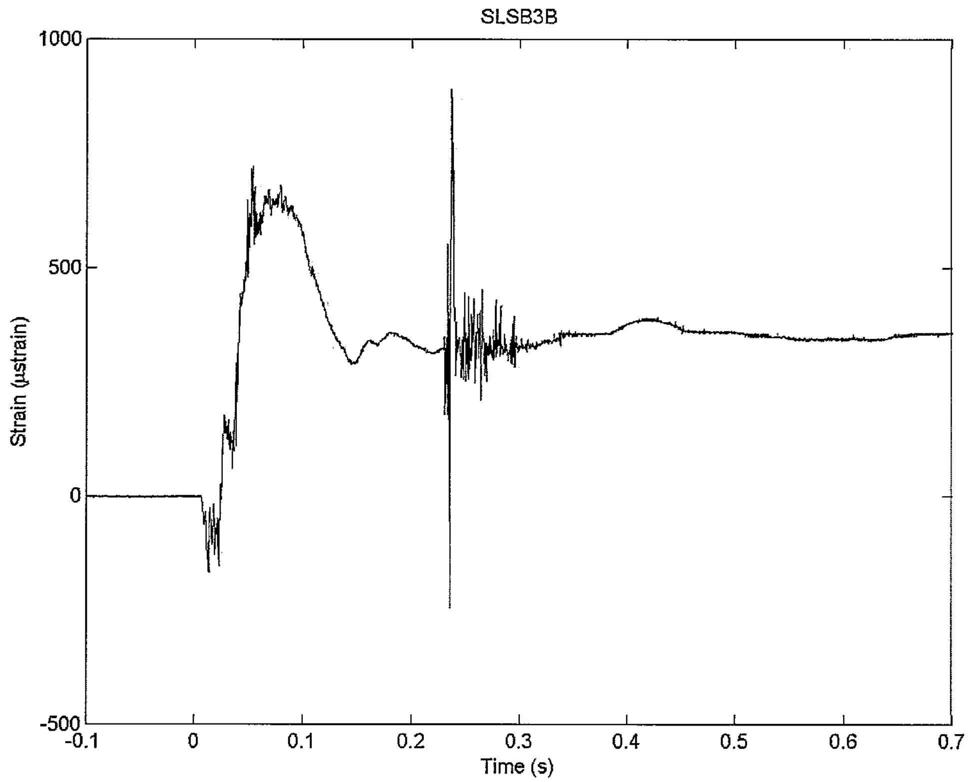

SCSGNTR
Strain (μstrain)
Time (s)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

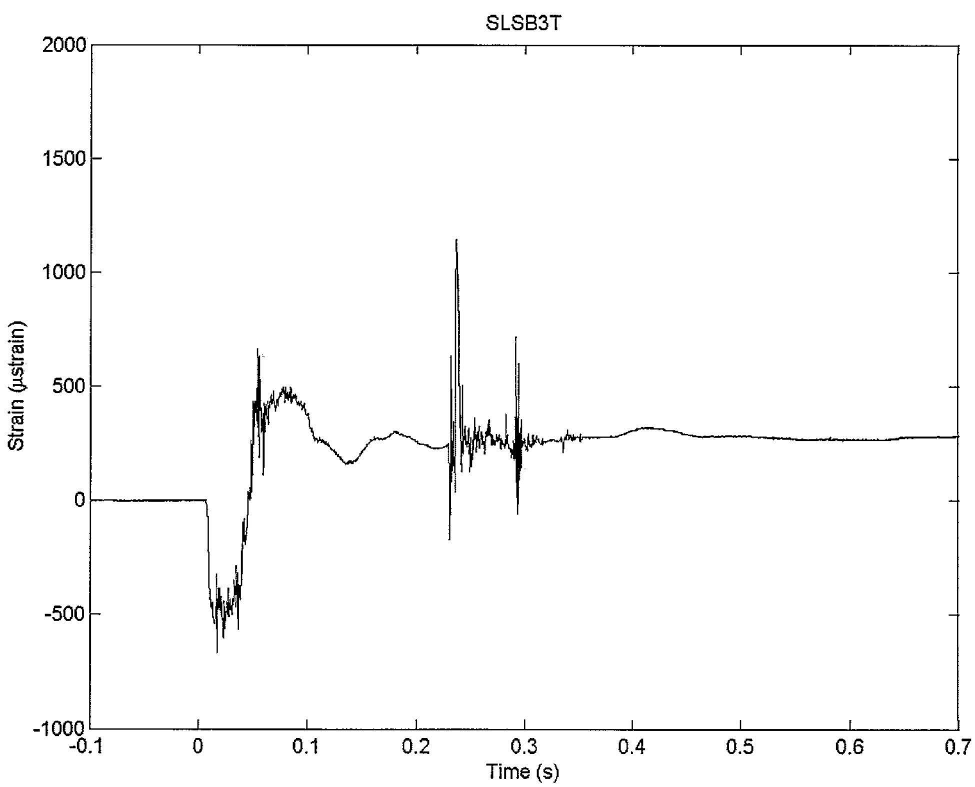

SLSB1B
Strain (μstrain)
Time (s)
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

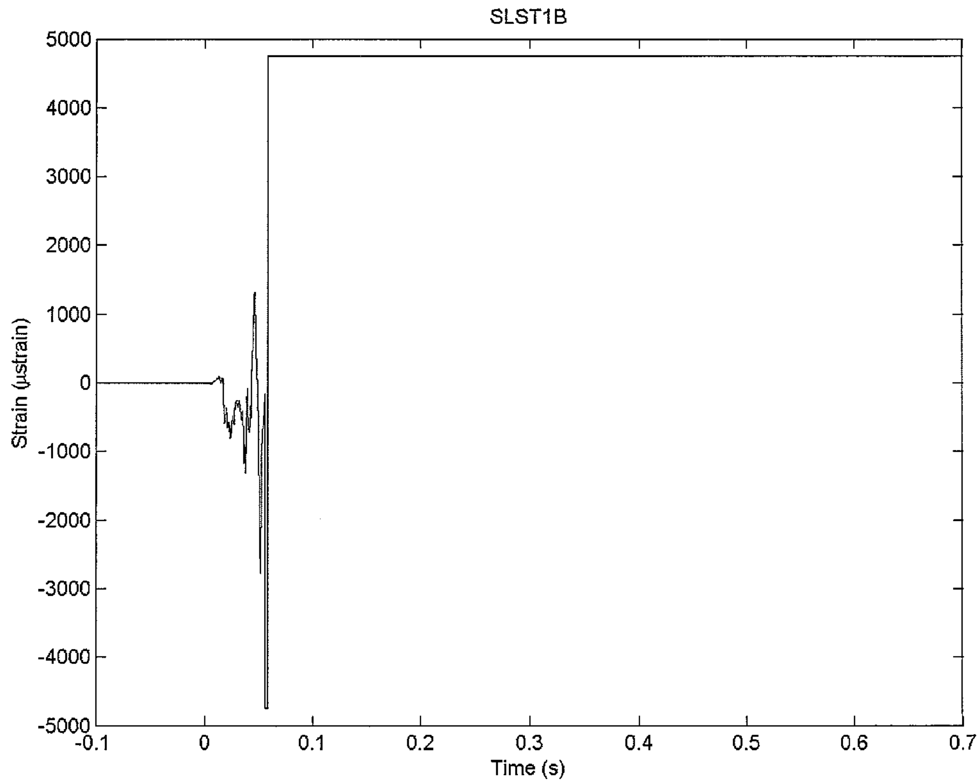

SLSB1T
Strain (μstrain)
Time (s)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

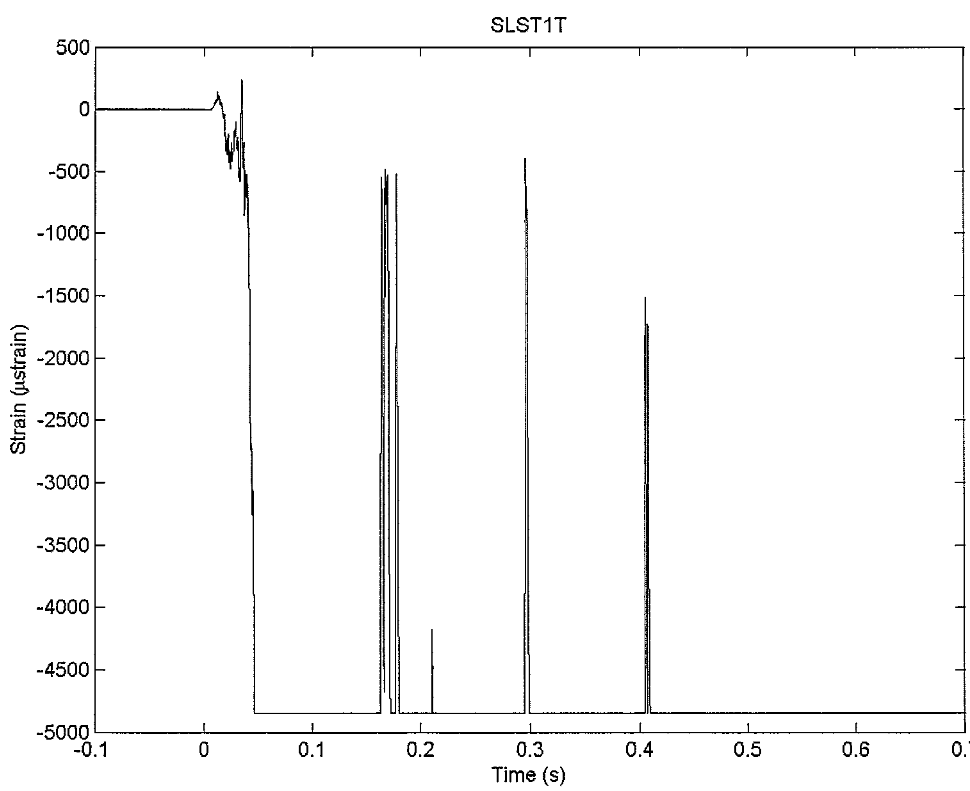

SLSB2B
Strain (µstrain)
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

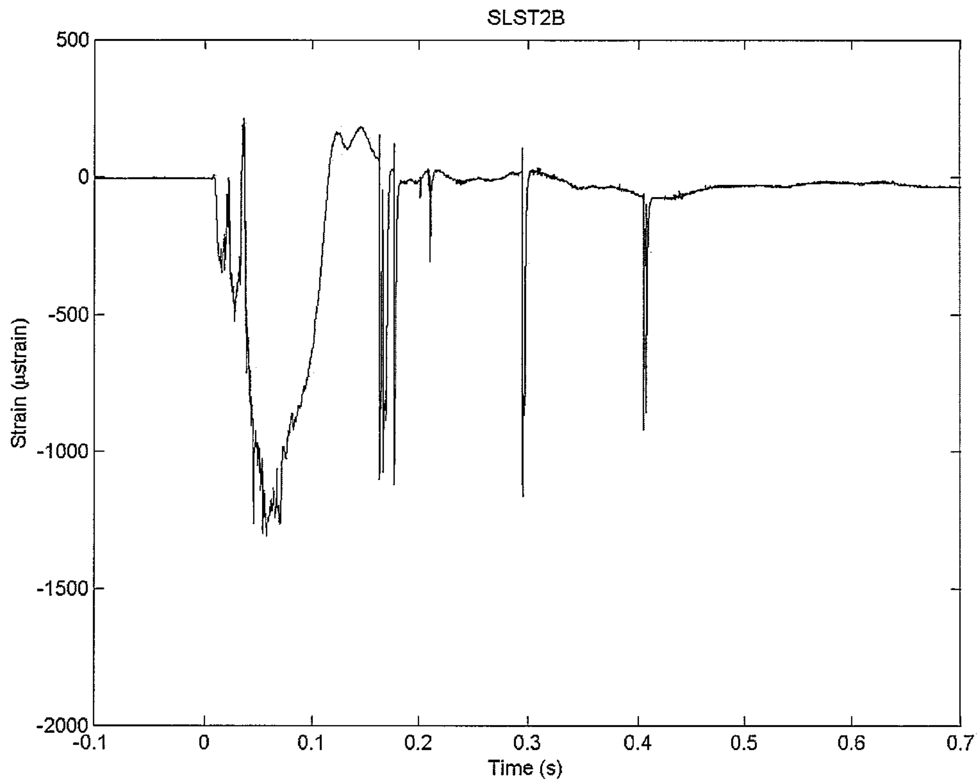

SLSB2T
Strain (µstrain)
1000
500
0
-500
-1000
-1500
-2000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

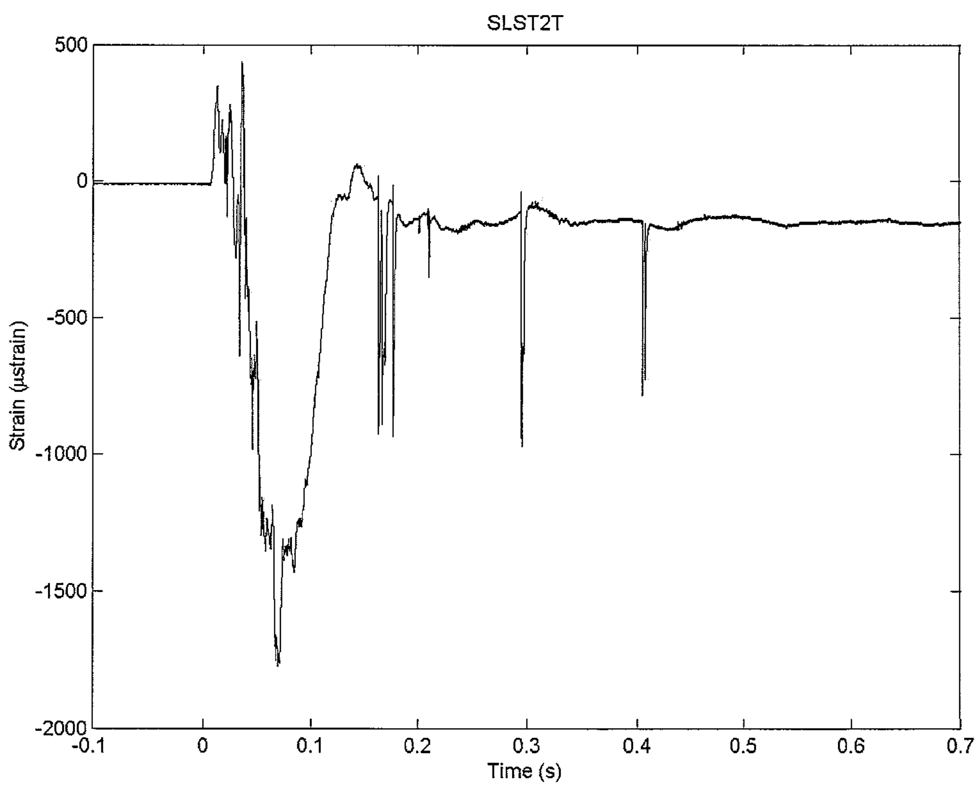

SLSB3B
Strain (µstrain)
1000
500
0
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

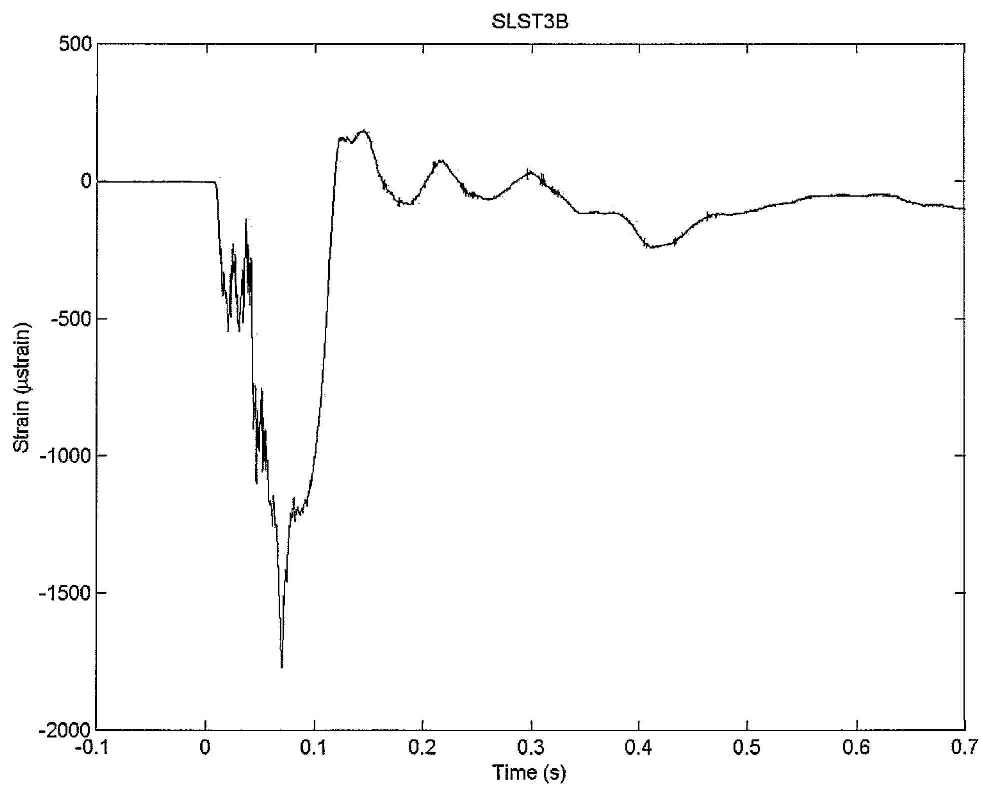

SLSB3T
Strain (µstrain)
2000
1500
1000
500
0
-500
-1000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

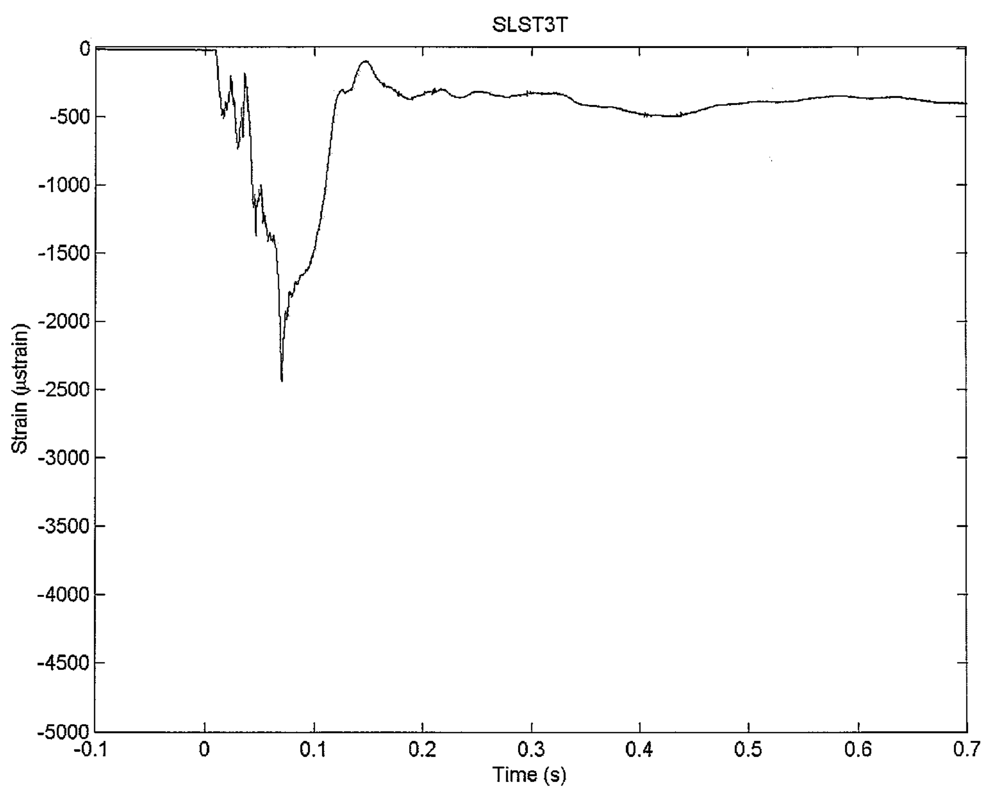

SLST1B
Strain (μstrain)
Time (s)
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

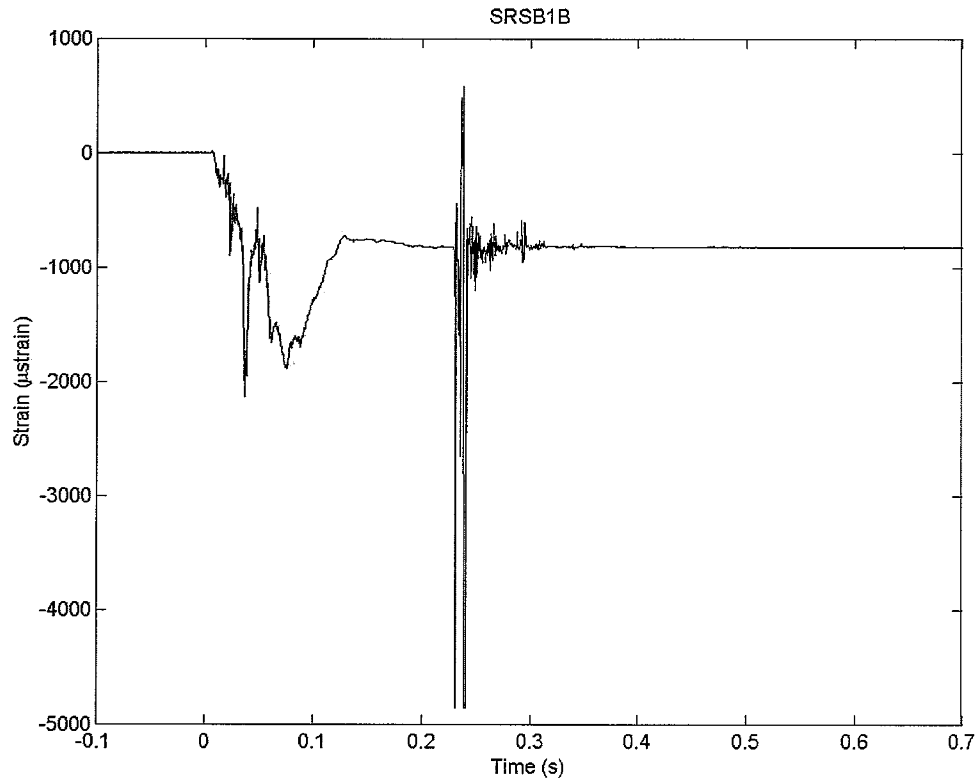

SLST1T
Strain (μstrain)
Time (s)
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

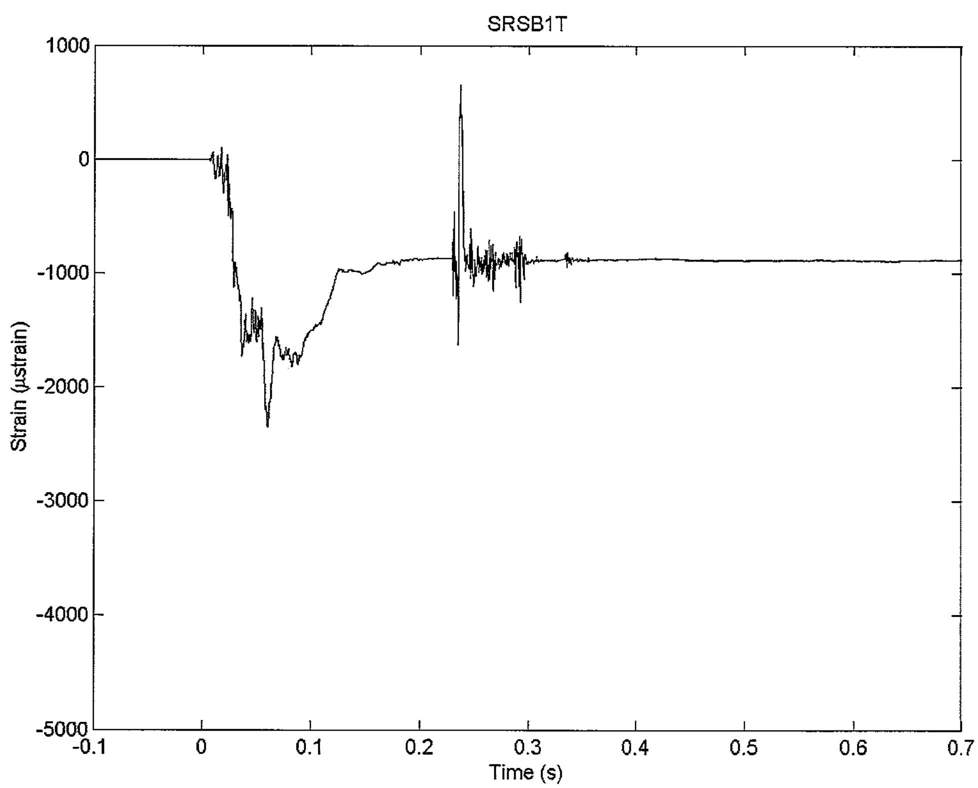

SLST2B
500
0
-500
-1000
-1500
-2000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

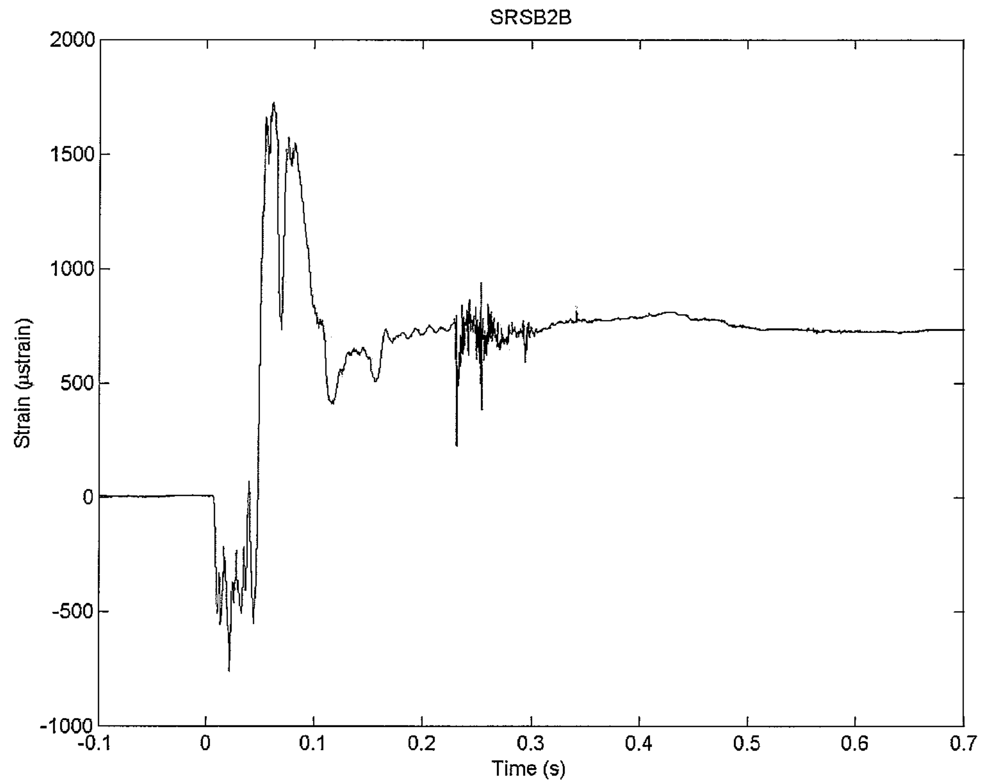

SLST2T
500
0
-500
-1000
-1500
-2000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

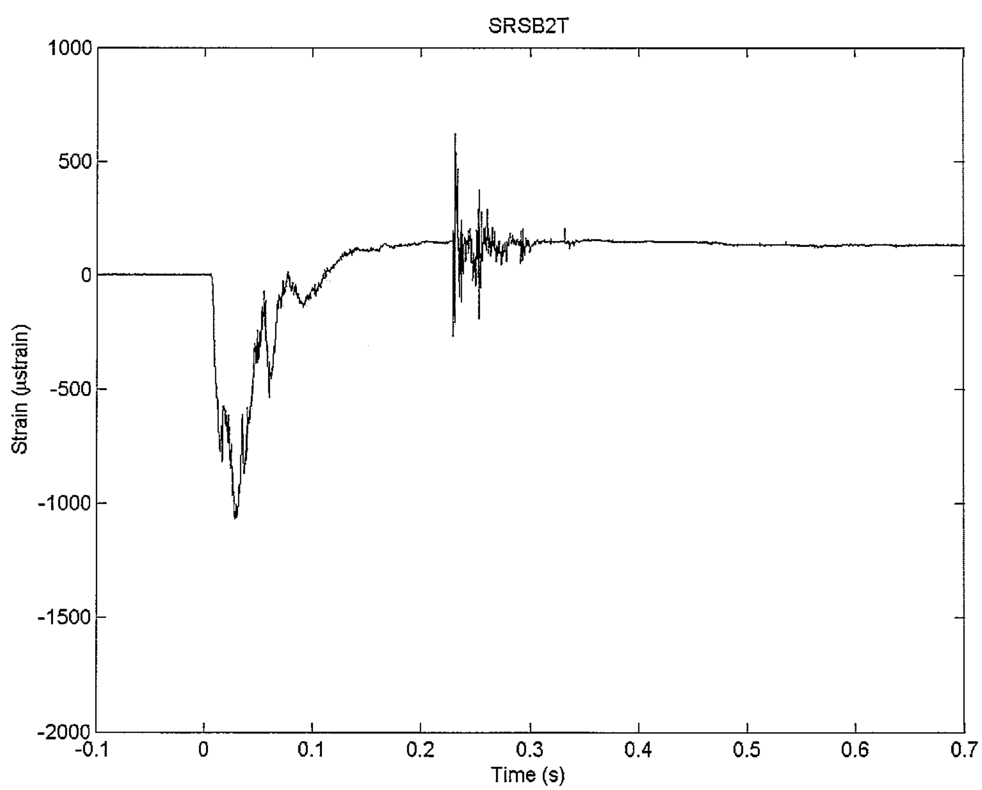

SLST3B
500
0
-500
-1000
-1500
-2000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

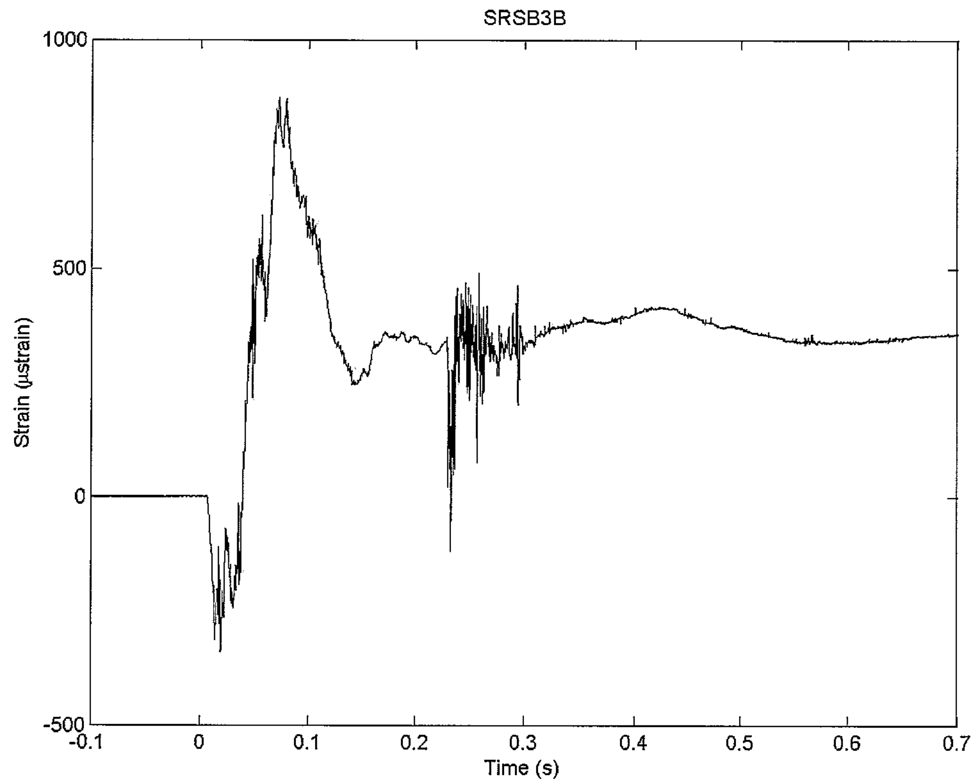

SLST3T
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

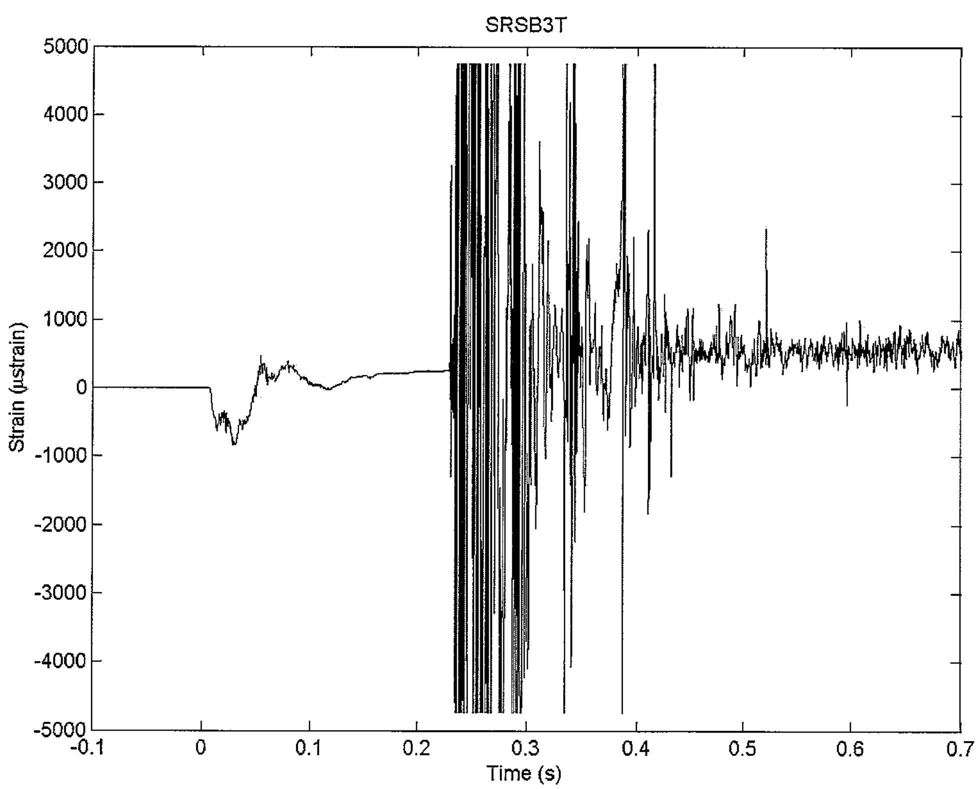

SRSB1B
1000
0
-1000
-2000
-3000
-4000
-5000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

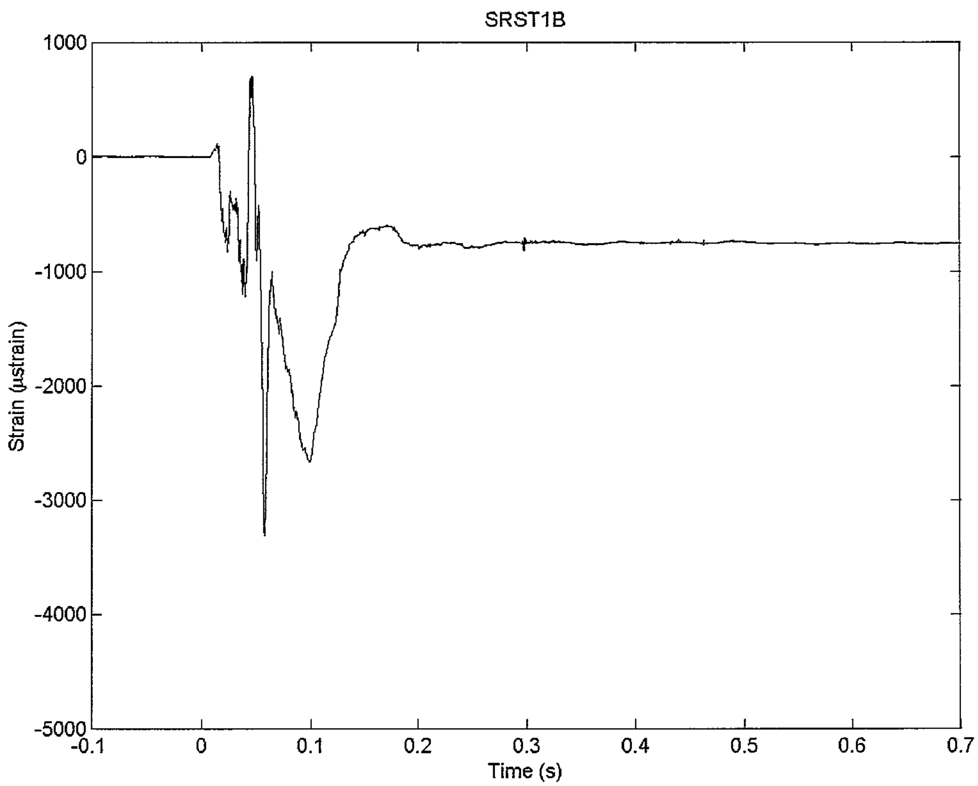

SRSB1T
1000
0
-1000
-2000
-3000
-4000
-5000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

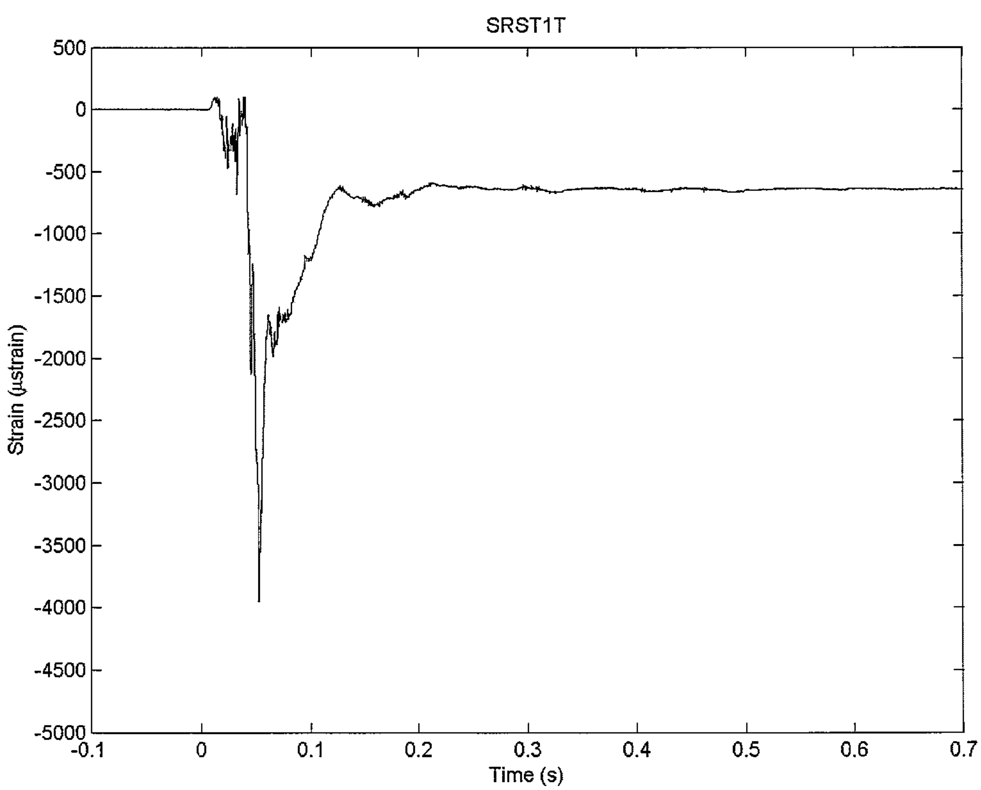

SRSB2B
2000
1500
1000
500
0
-500
-1000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

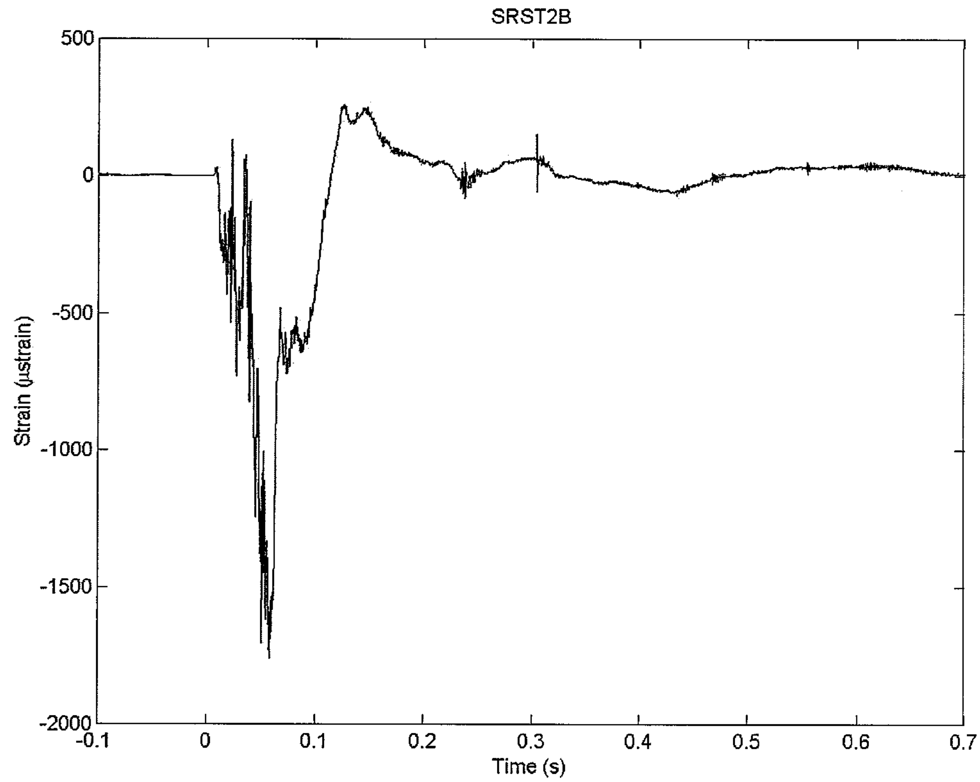

SRSB2T
1000
500
0
-500
-1000
-1500
-2000
Strain (µstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

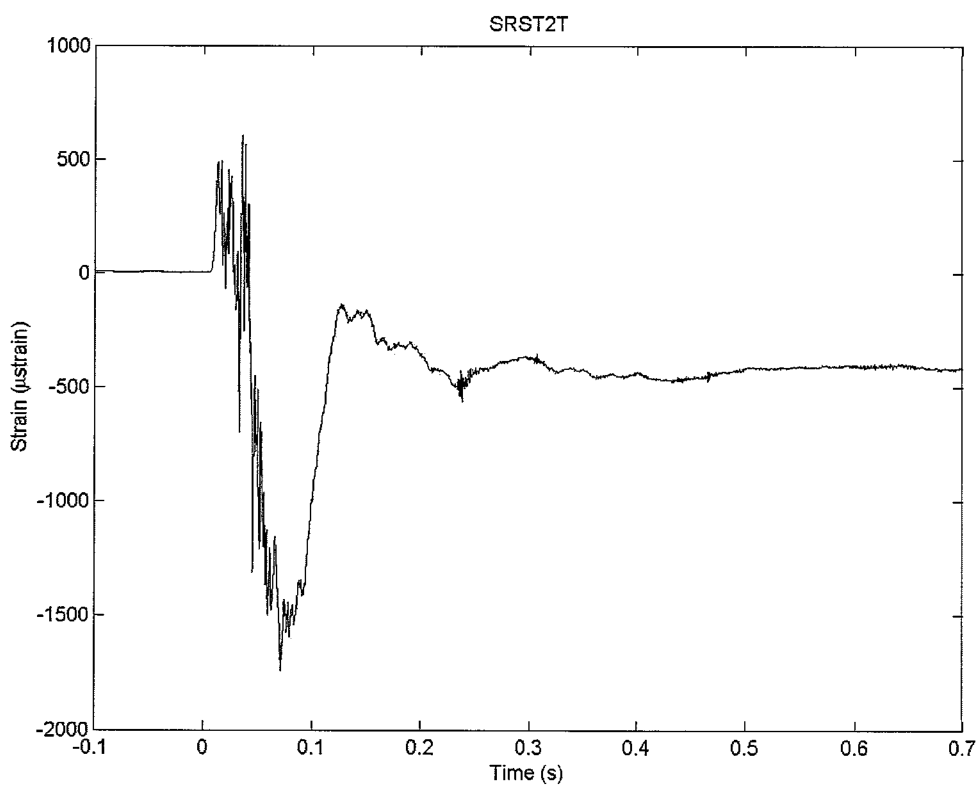

SRSB3B
1000
500
0
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)
Strain (μstrain)

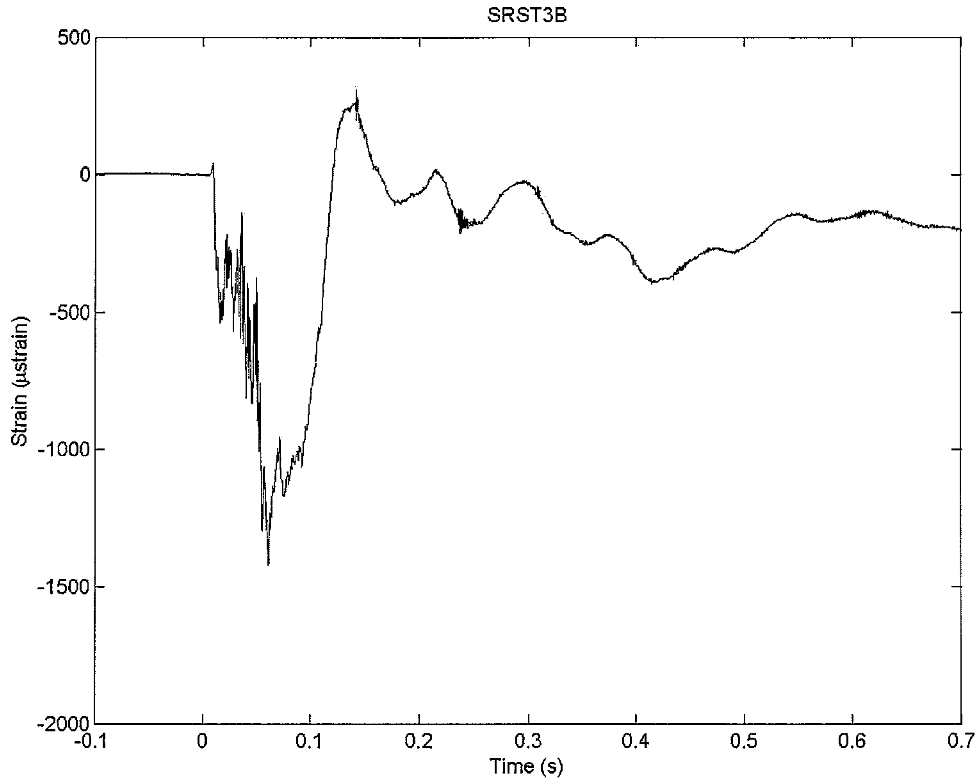

SRSB3T
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)
Strain (μstrain)

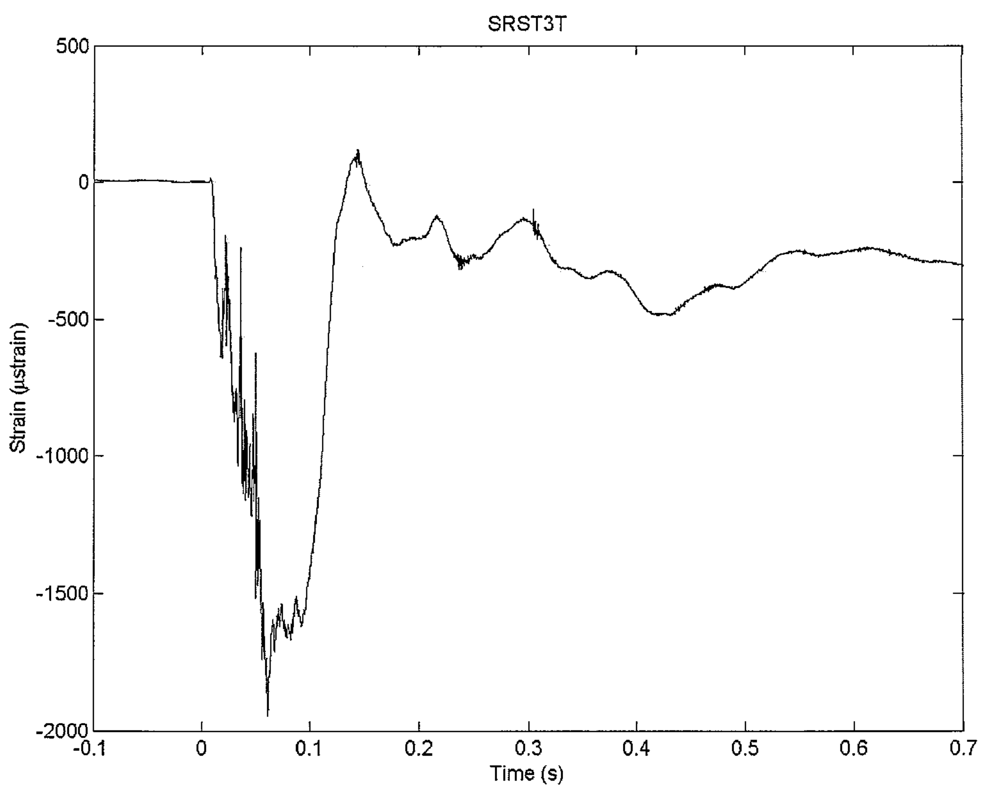

SRST1B
Strain (µstrain)
Time (s)
1000
0
-1000
-2000
-3000
-4000
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


SRST1T
Strain (µstrain)
Time (s)
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


SRST2B
500
0
-500
-1000
-1500
-2000
Strain (μstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)


SRST2T
1000
500
0
-500
-1000
-1500
-2000
Strain (μstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)


SRST3B
500
0
-500
-1000
-1500
-2000
Strain (μstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)


SRST3T
500
0
-500
-1000
-1500
-2000
Strain (μstrain)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)

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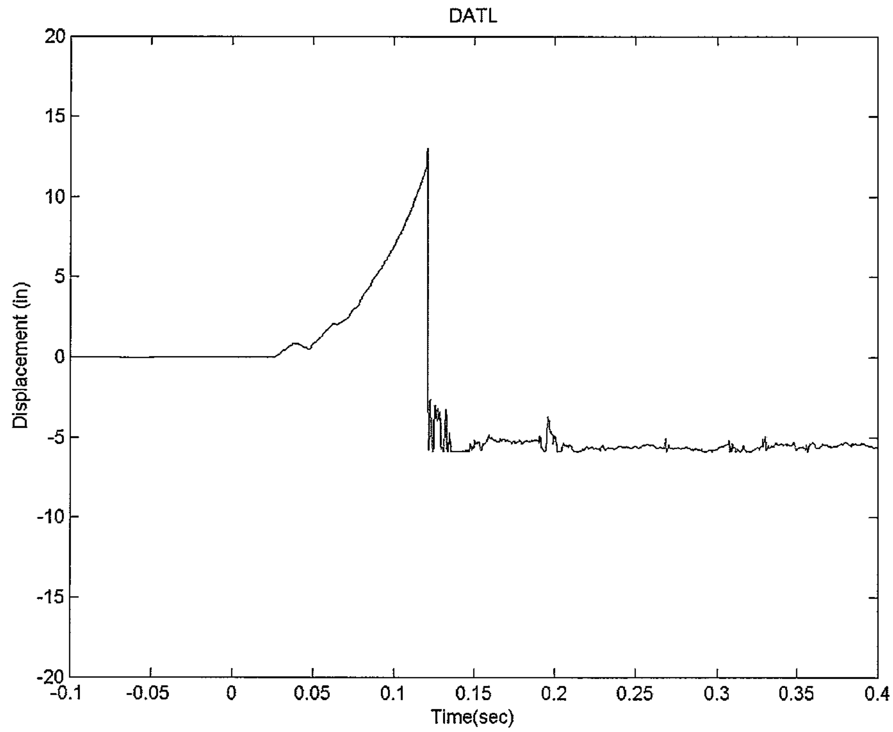
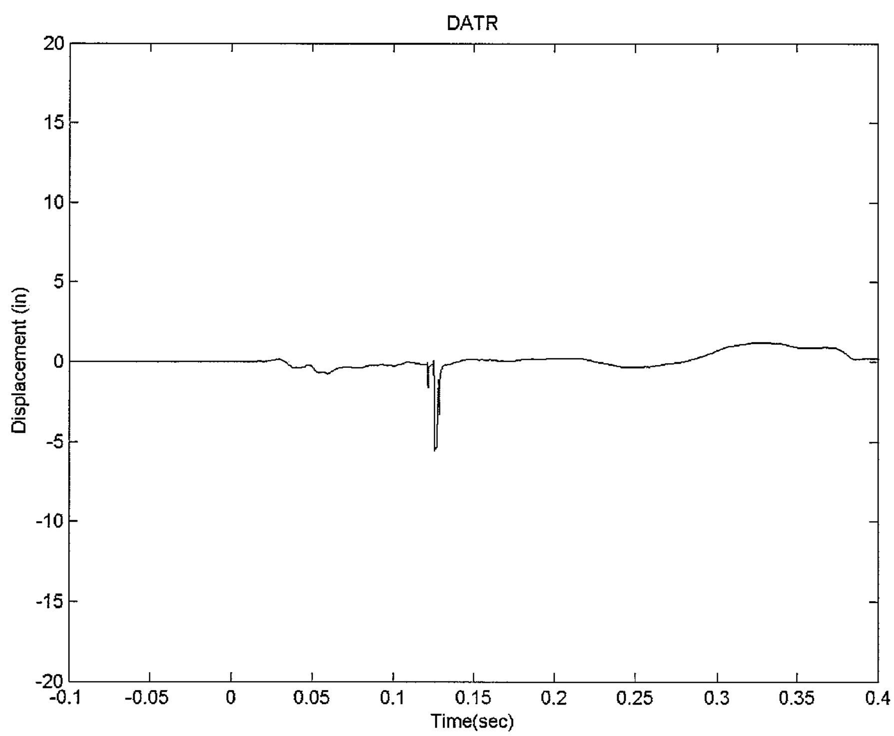
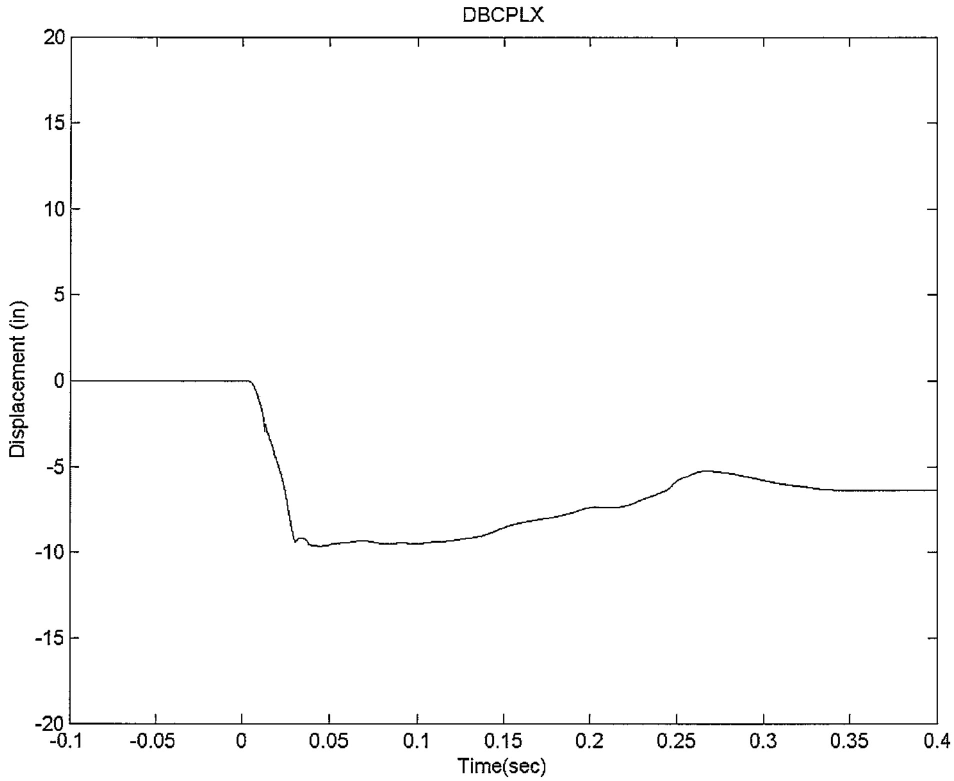
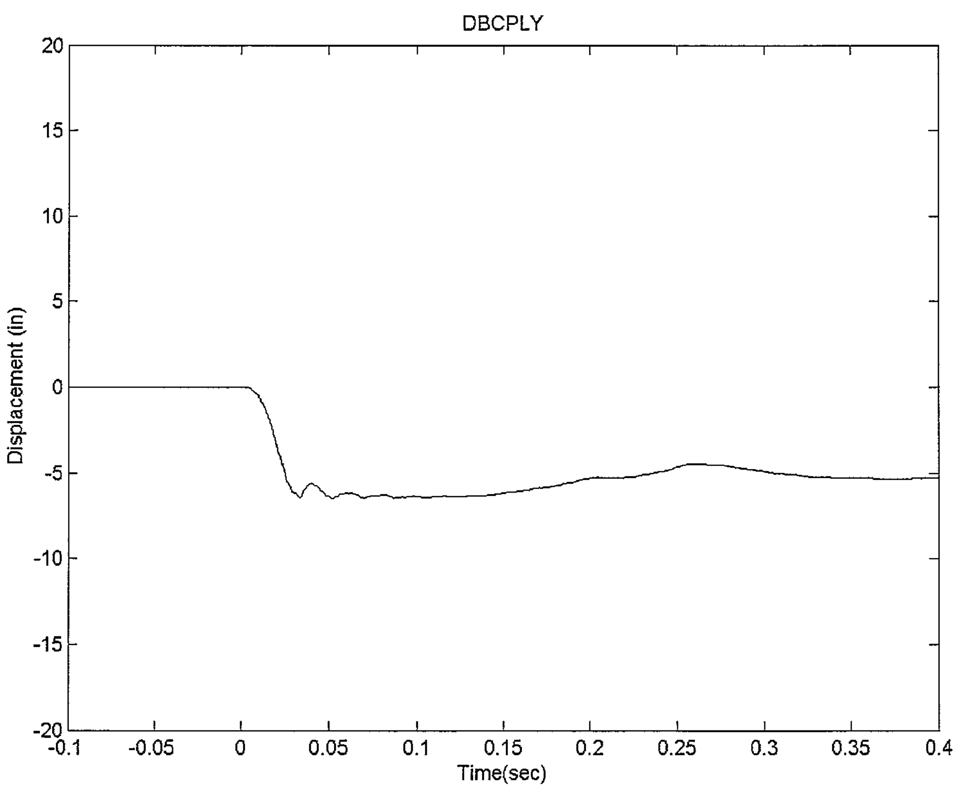
APPENDIX D.

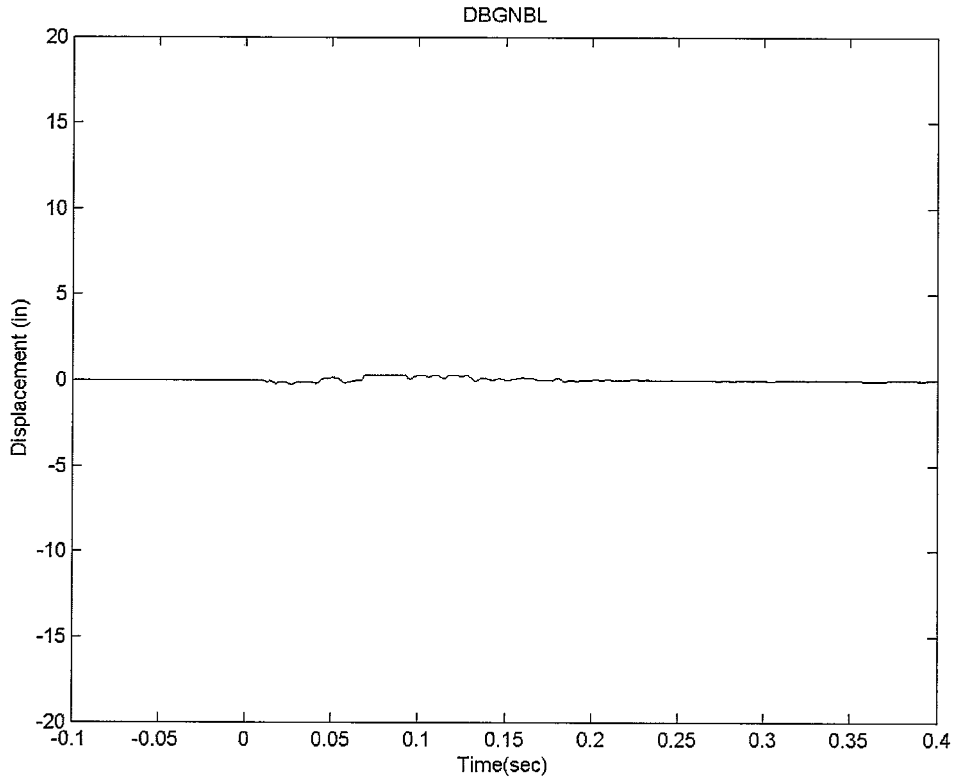
Displacement Plots

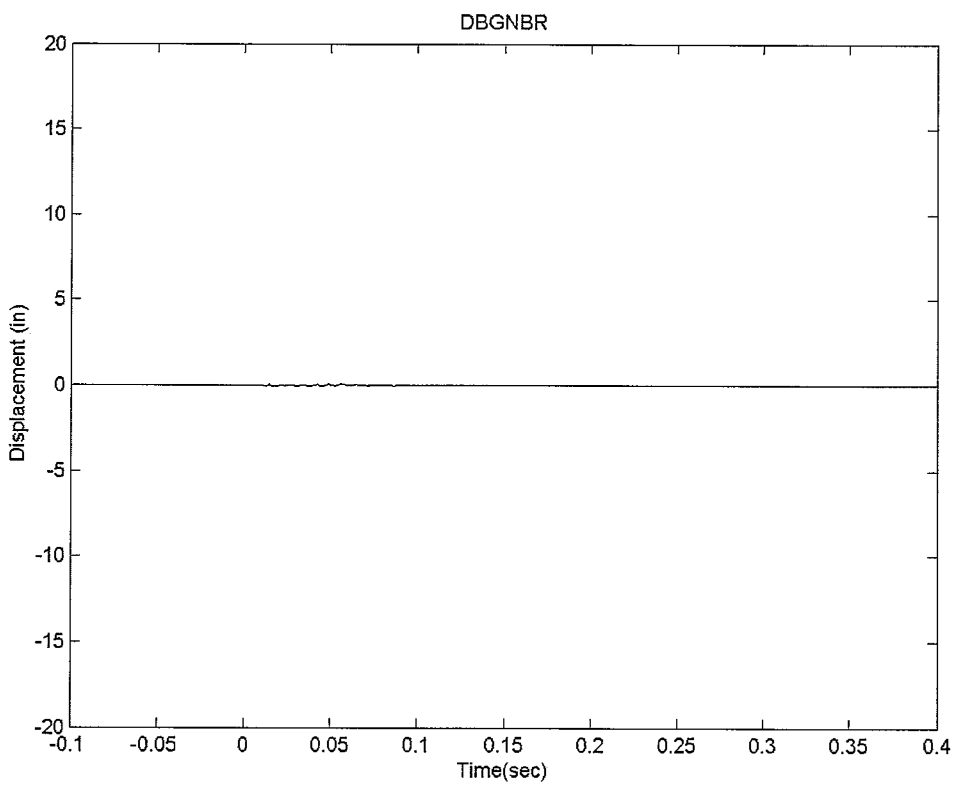

DATL
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

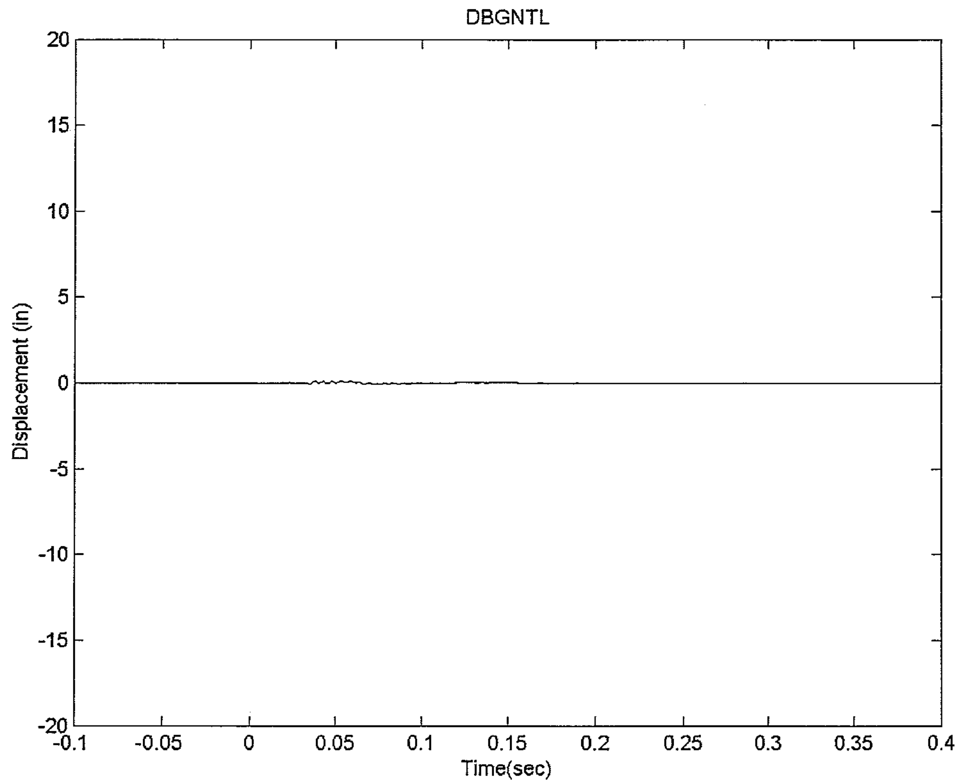

DATR
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4


DBCPLX
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4


DBCPLY
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4


DBGNBL
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4


DBGNBR
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4


DBGNTL
Displacement (in)
Time(sec)
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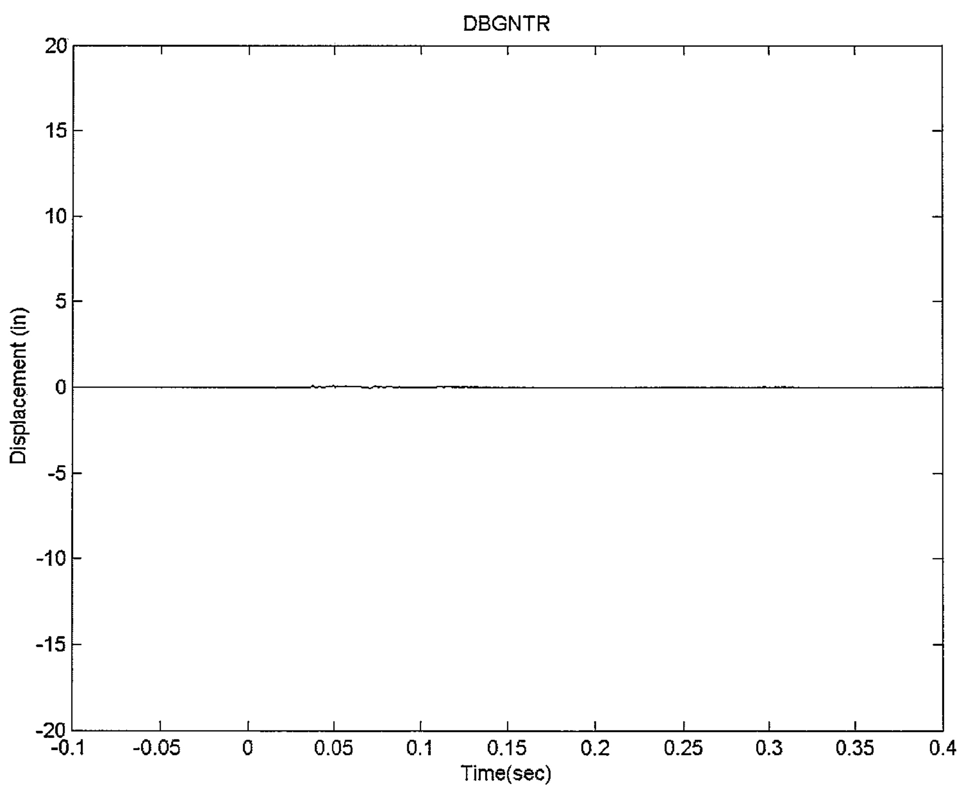
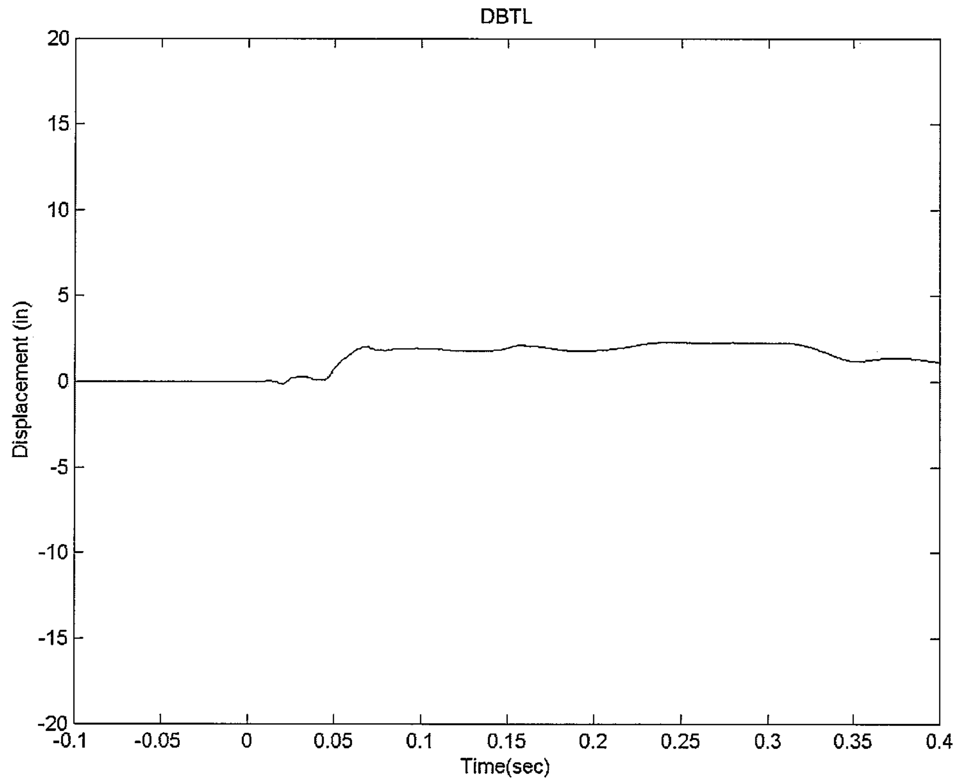
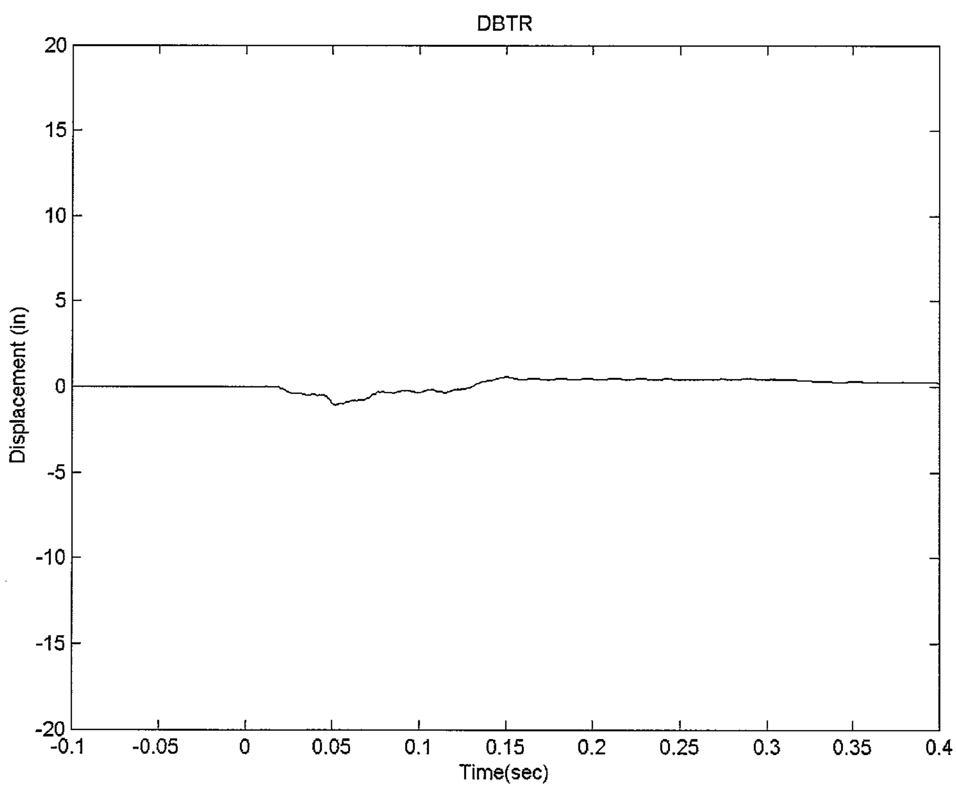
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

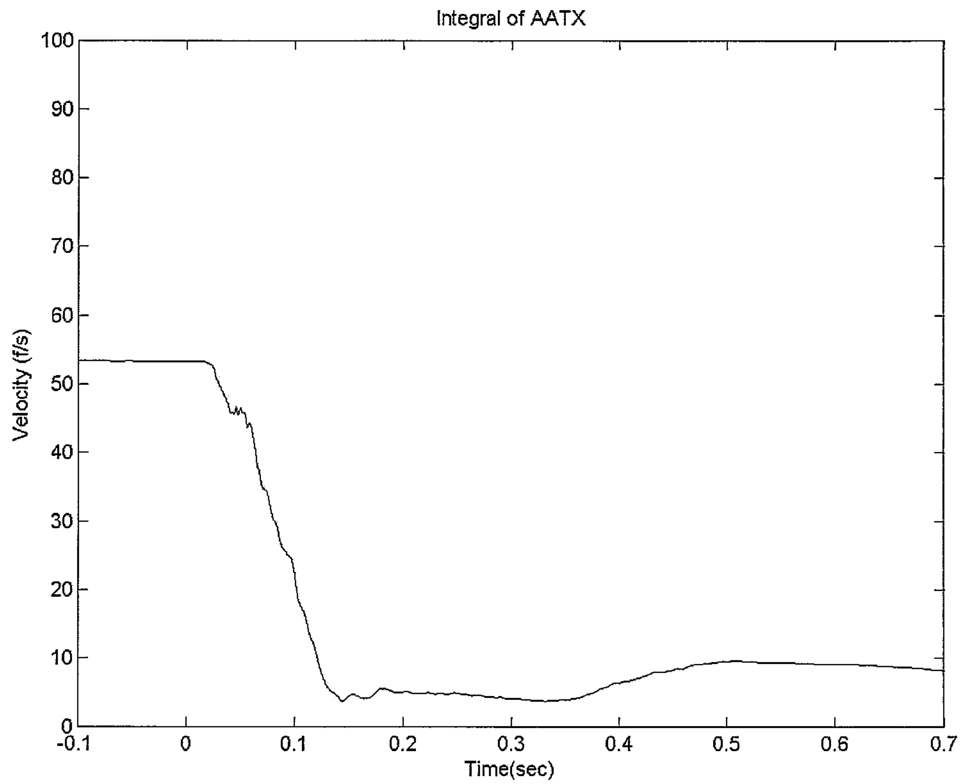

DBGNTR
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

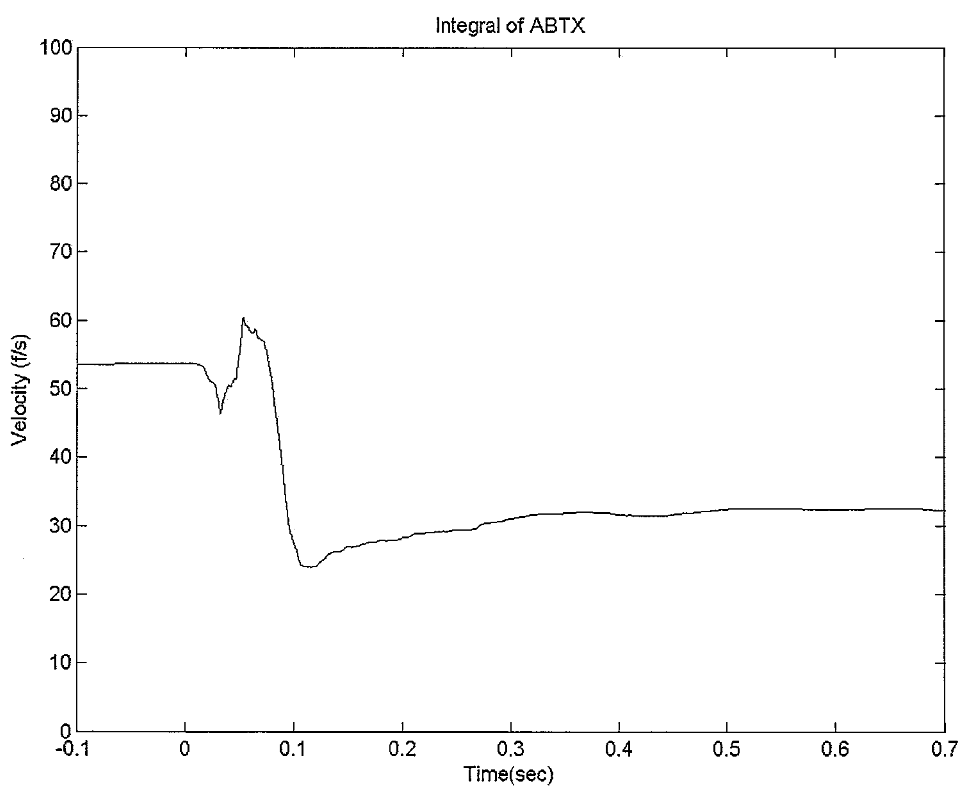

DBTL
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

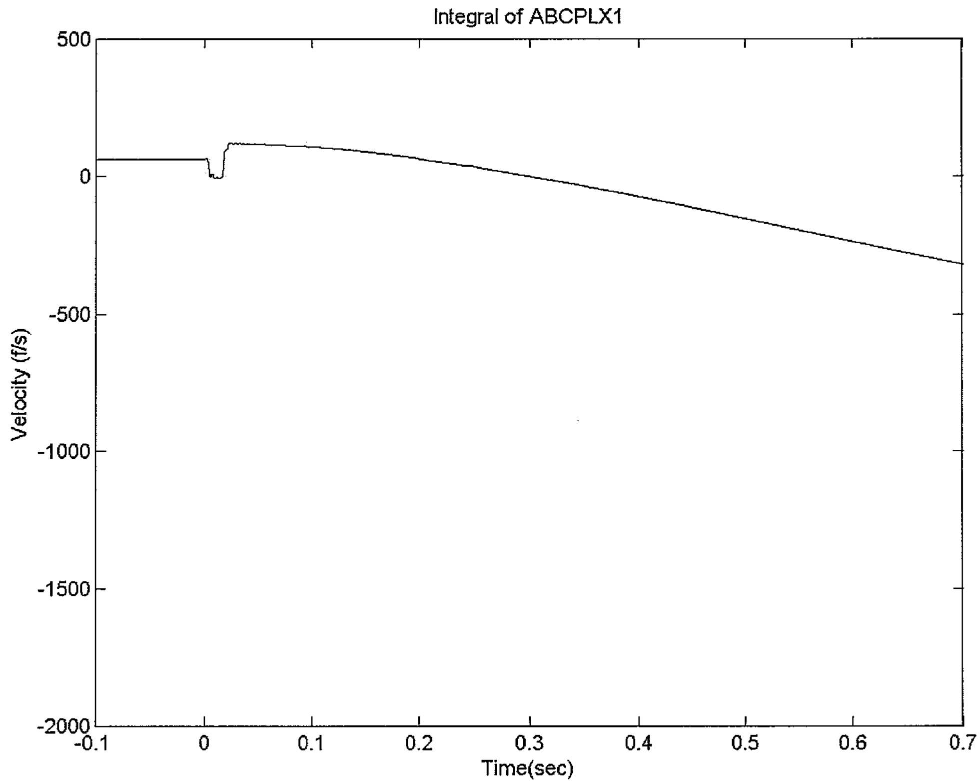

DBTR
Displacement (in)
Time(sec)
20
15
10
5
0
-5
-10
-15
-20
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

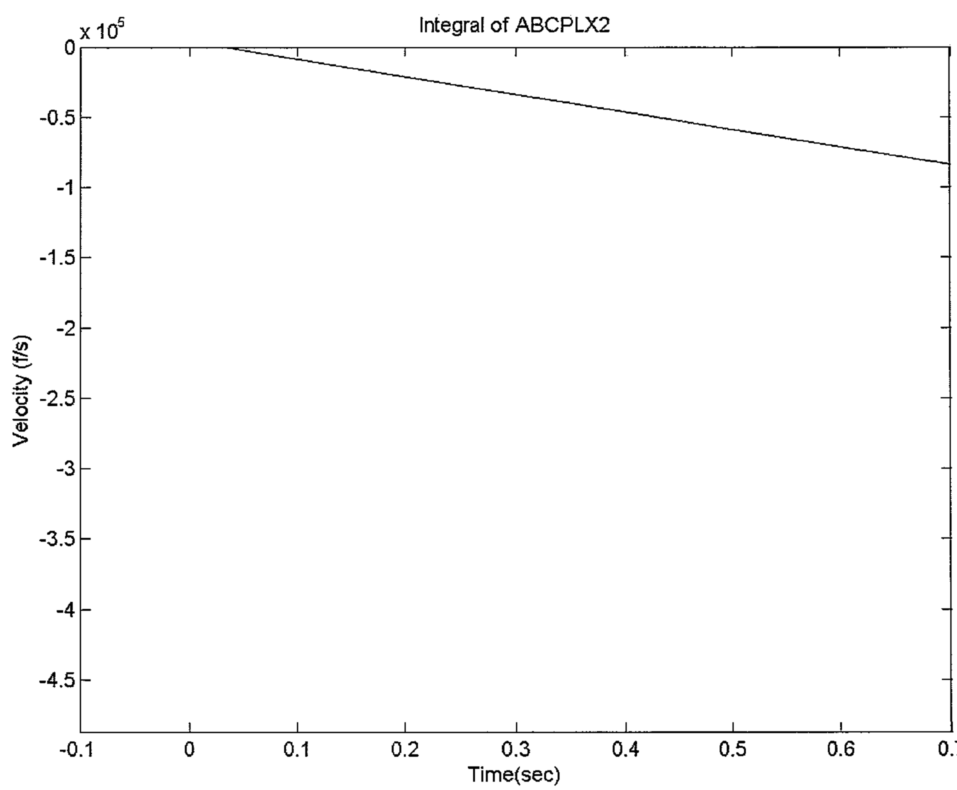
APPENDIX E.

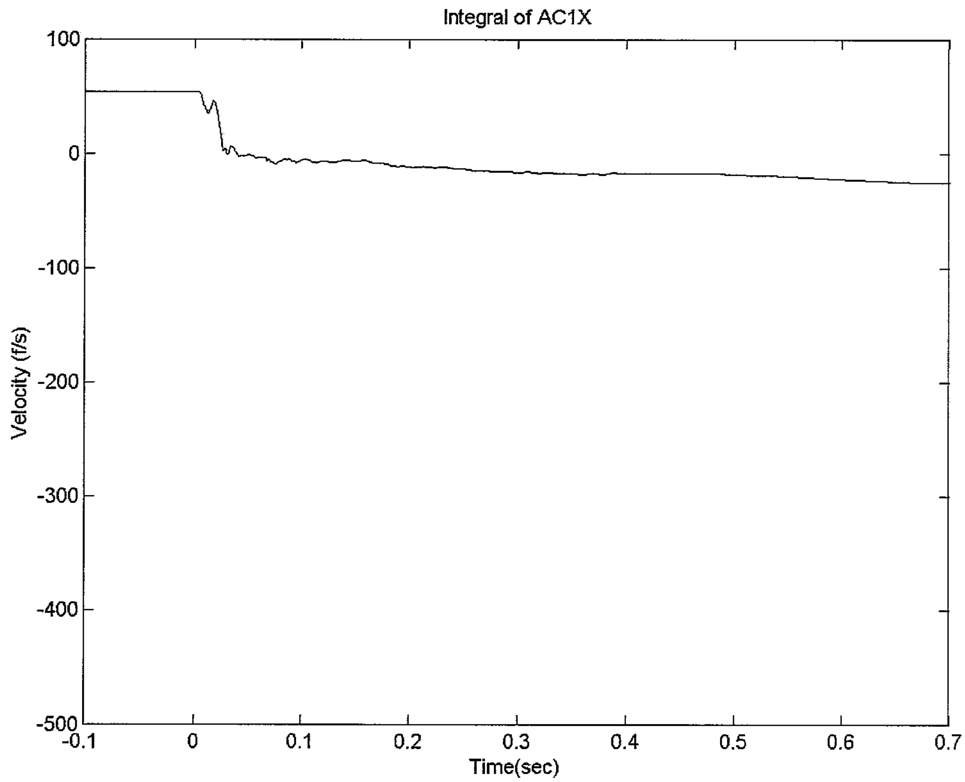
Velocity Plots


Integral of AATX
Velocity (f/s)
Time(sec)
100
90
80
70
60
50
40
30
20
10
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

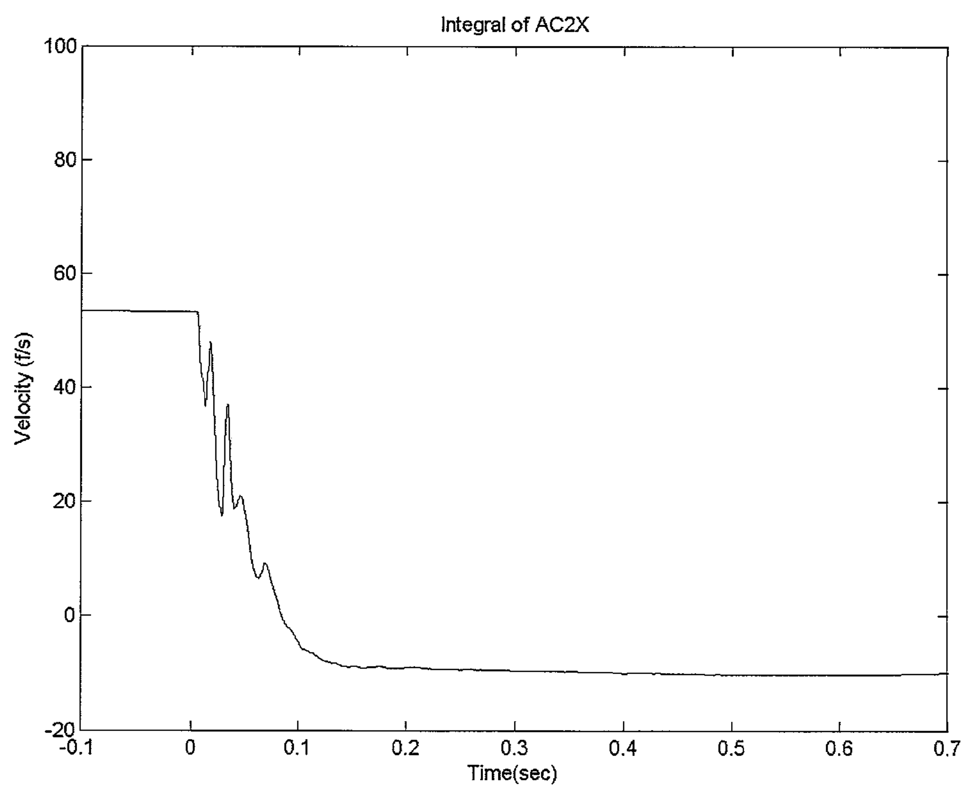

Integral of ABTX
Velocity (f/s)
Time(sec)
100
90
80
70
60
50
40
30
20
10
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Integral of ABCPLX1
Velocity (f/s)
Time(sec)
500
0
-500
-1000
-1500
-2000
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

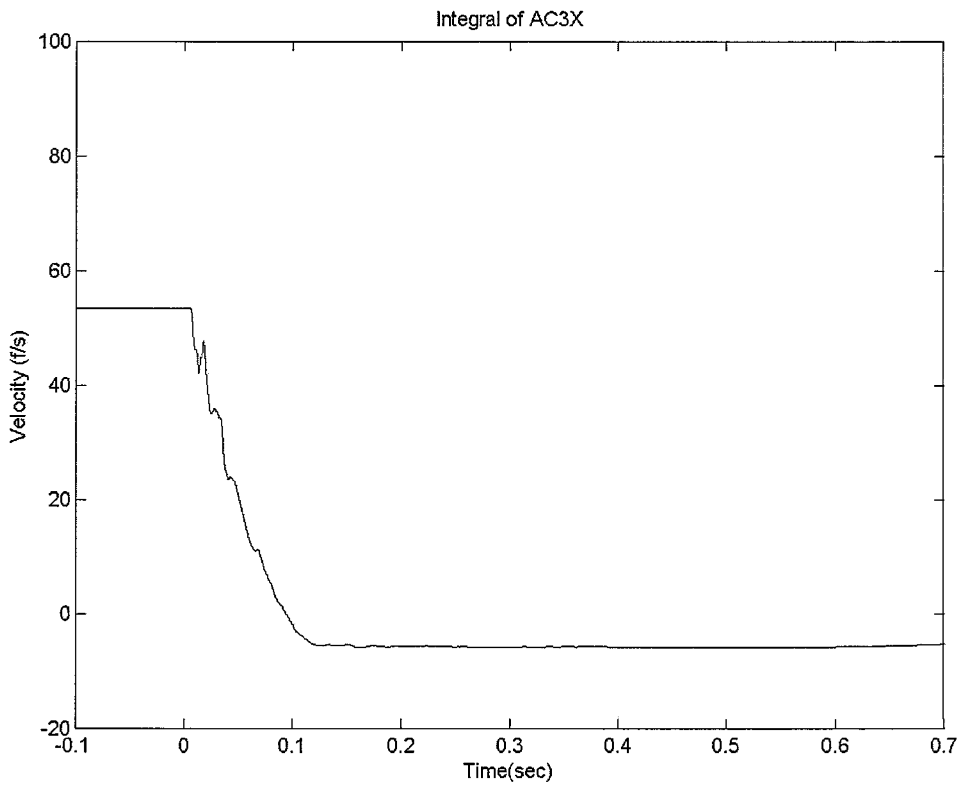

Integral of ABCPLX2
x 10^5
Velocity (f/s)
Time(sec)
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

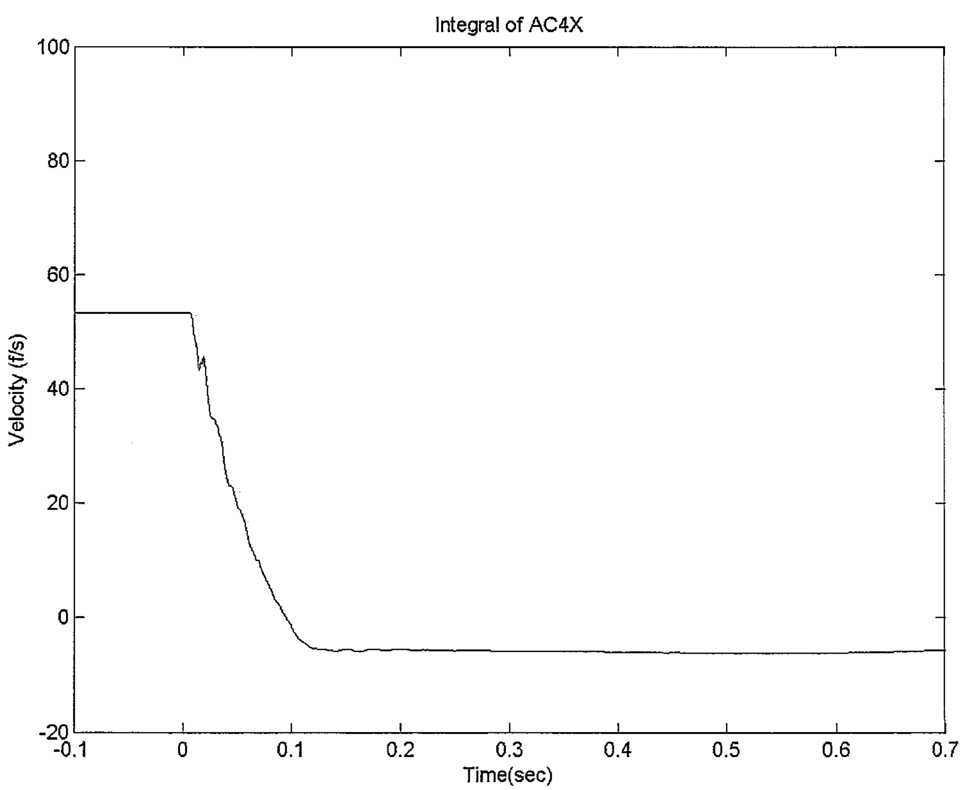


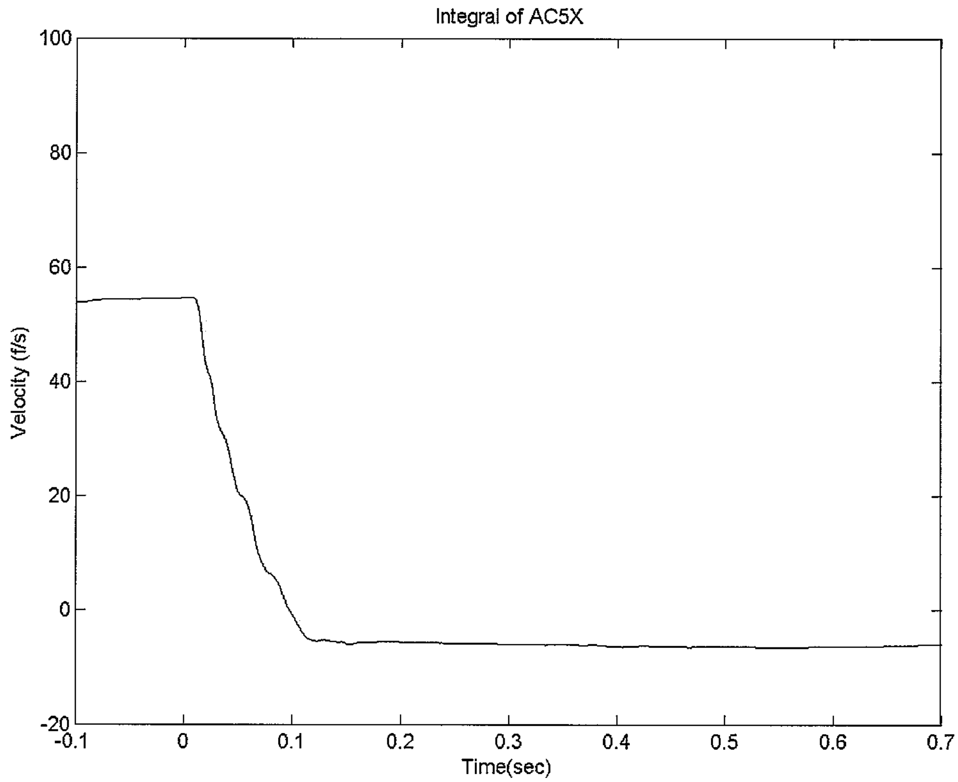
Integral of AC1X
Velocity (f/s)
Time(sec)
100
0
-100
-200
-300
-400
-500
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

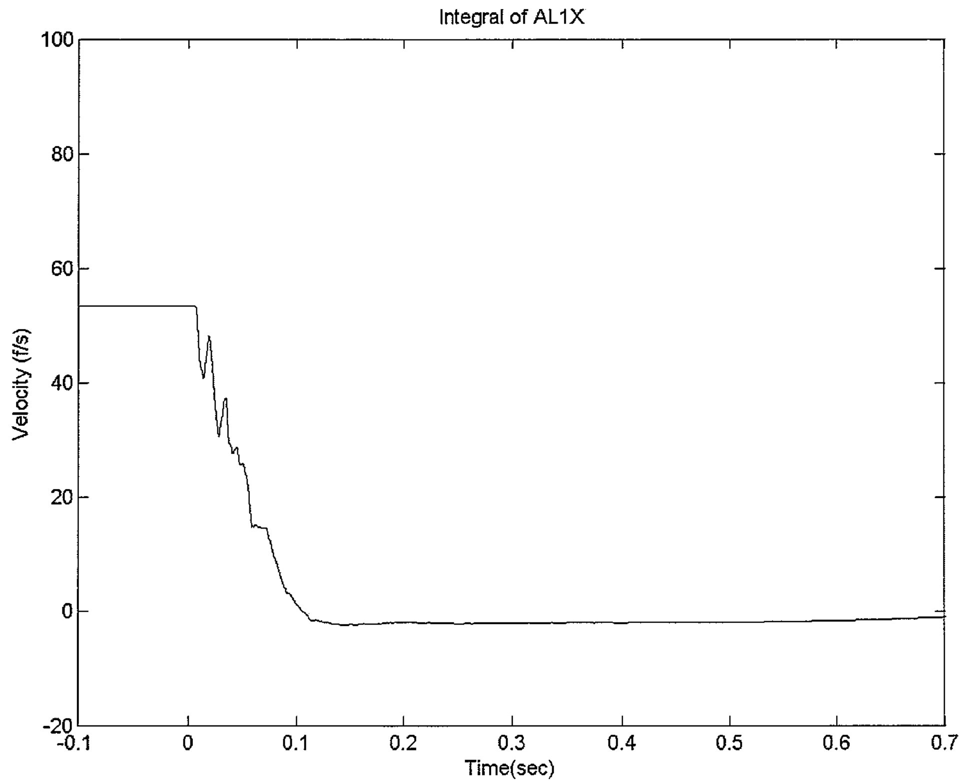


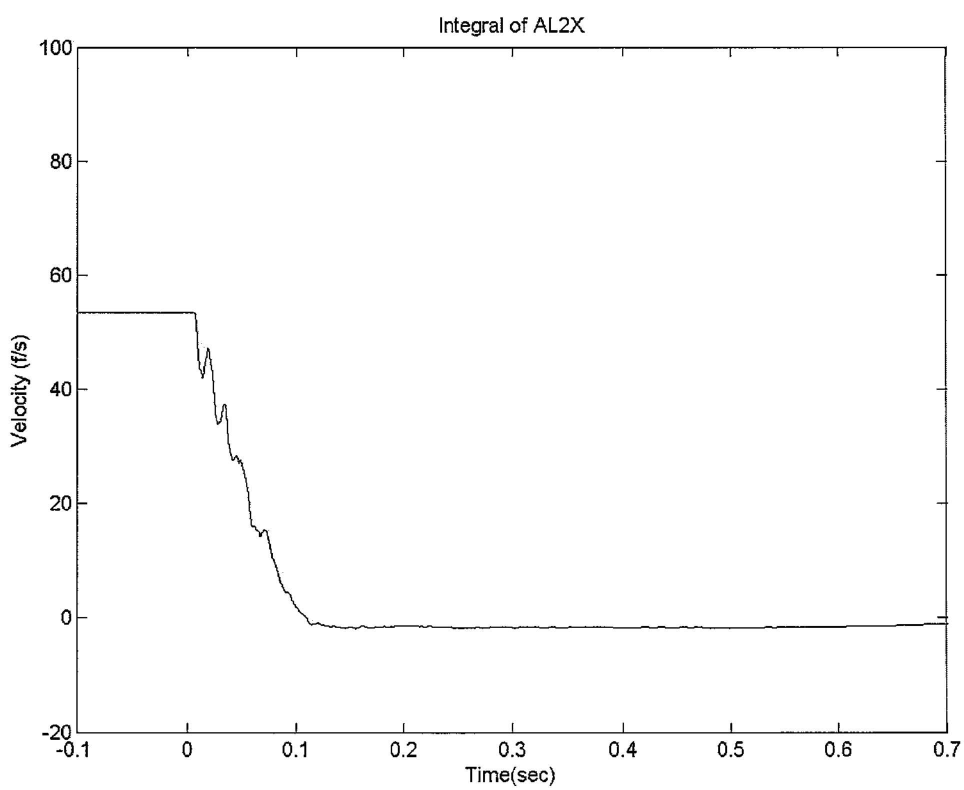
Integral of AC2X
Velocity (f/s)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

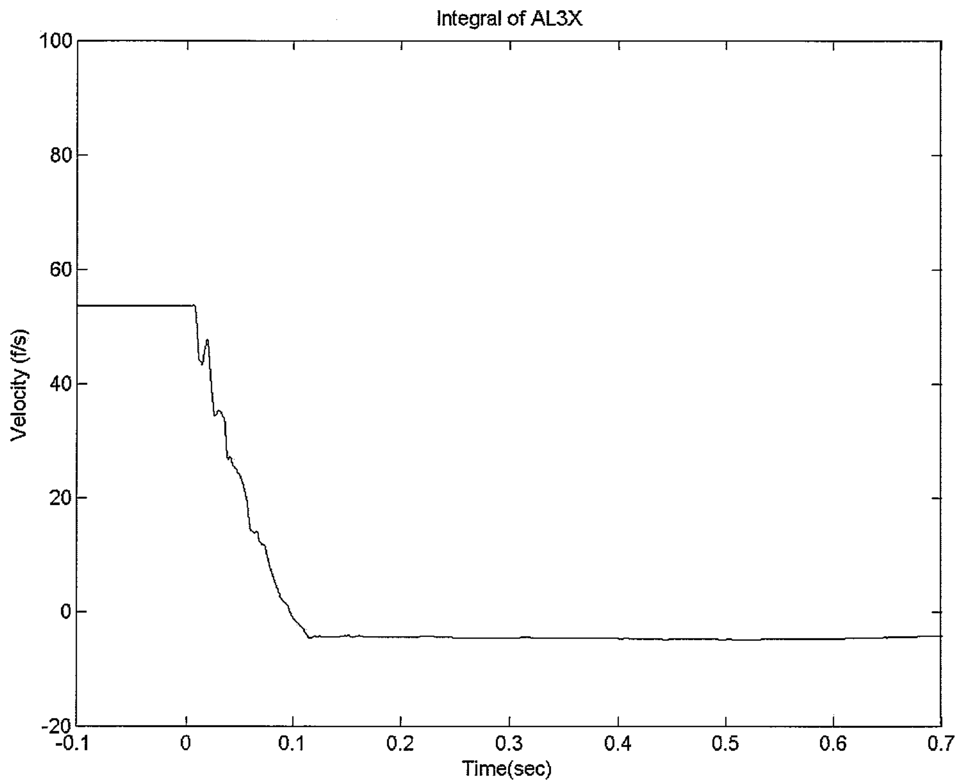

Integral of AC3X
100
80
60
40
20
0
-20
Velocity (f/s)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


Integral of AC4X
100
80
60
40
20
0
-20
Velocity (f/s)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)

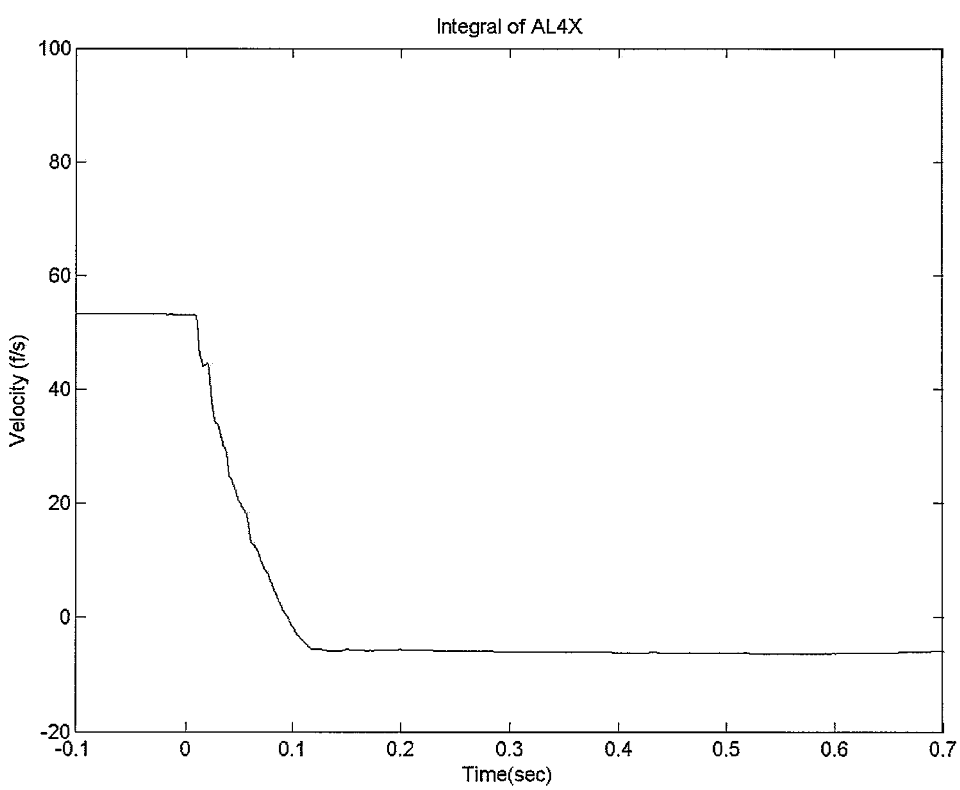

Integral of AC5X
100
80
60
40
20
0
-20
Velocity (f/s)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


Integral of AL1X
Velocity (f/s)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

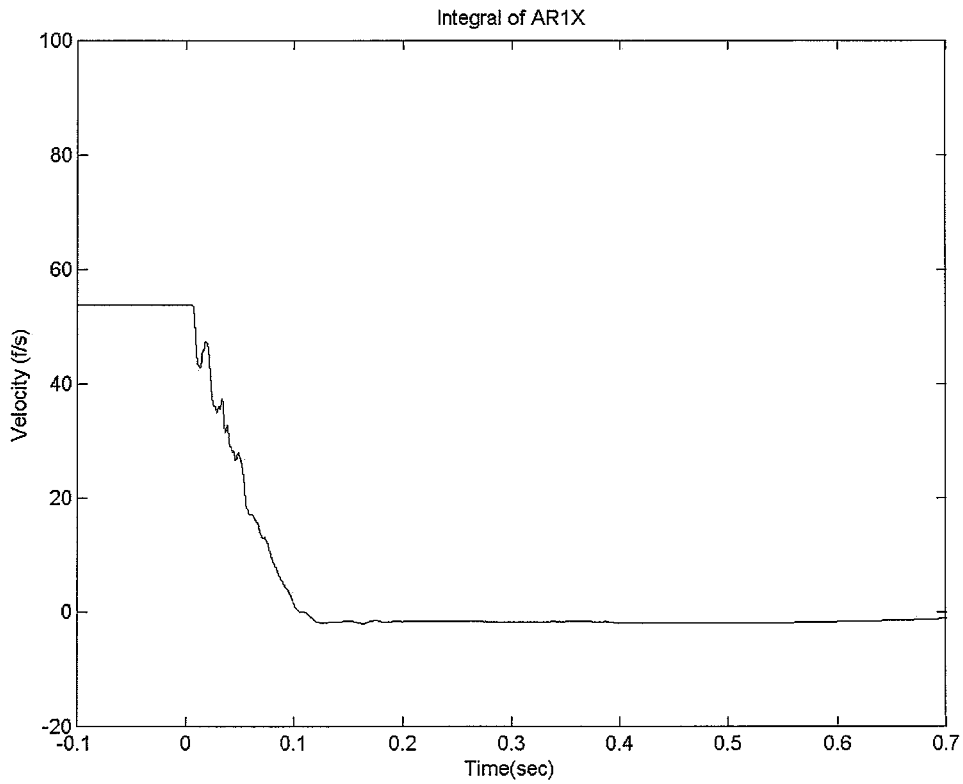

Integral of AL2X
Velocity (f/s)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7



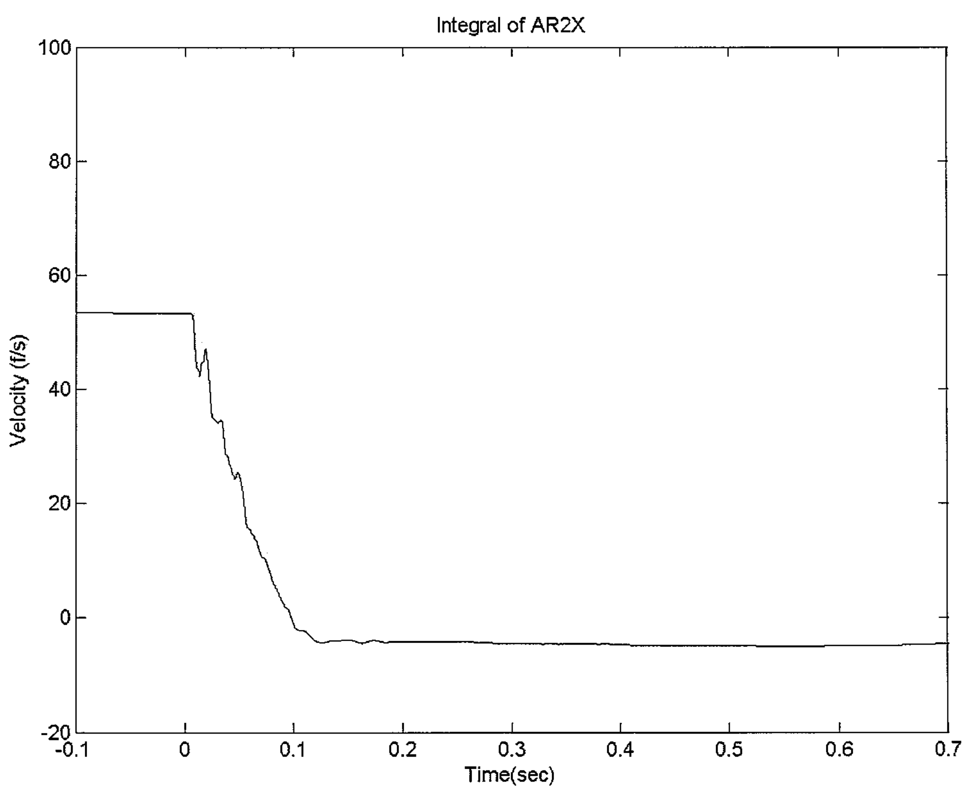
Integral of AL3X
Velocity (f/s)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7



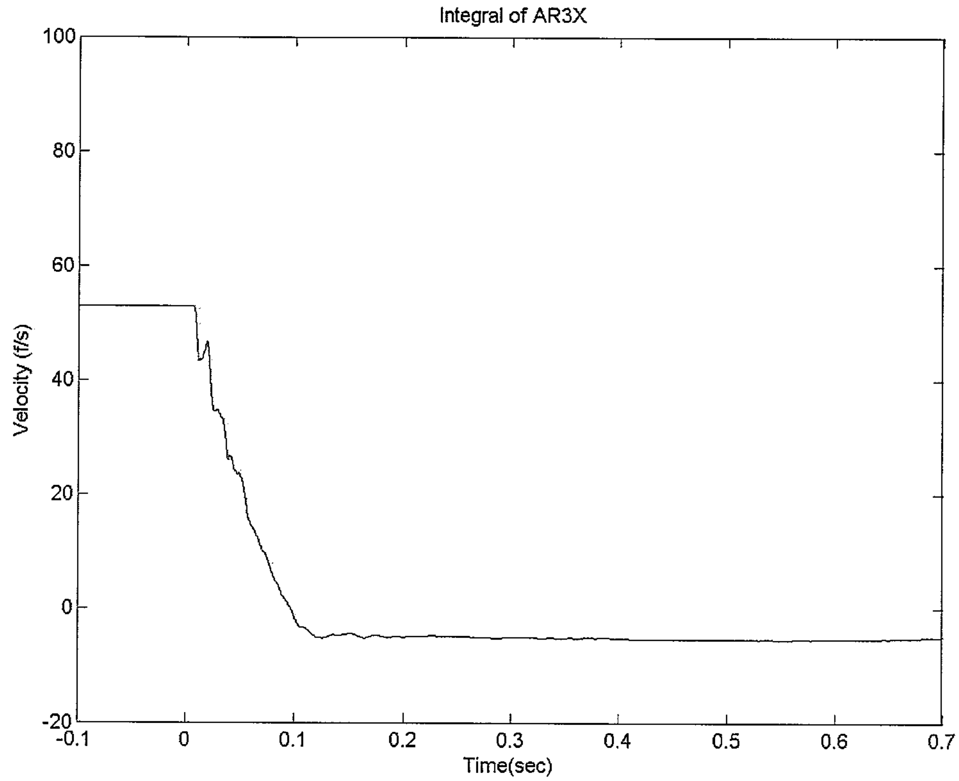
Integral of AL4X
Velocity (f/s)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

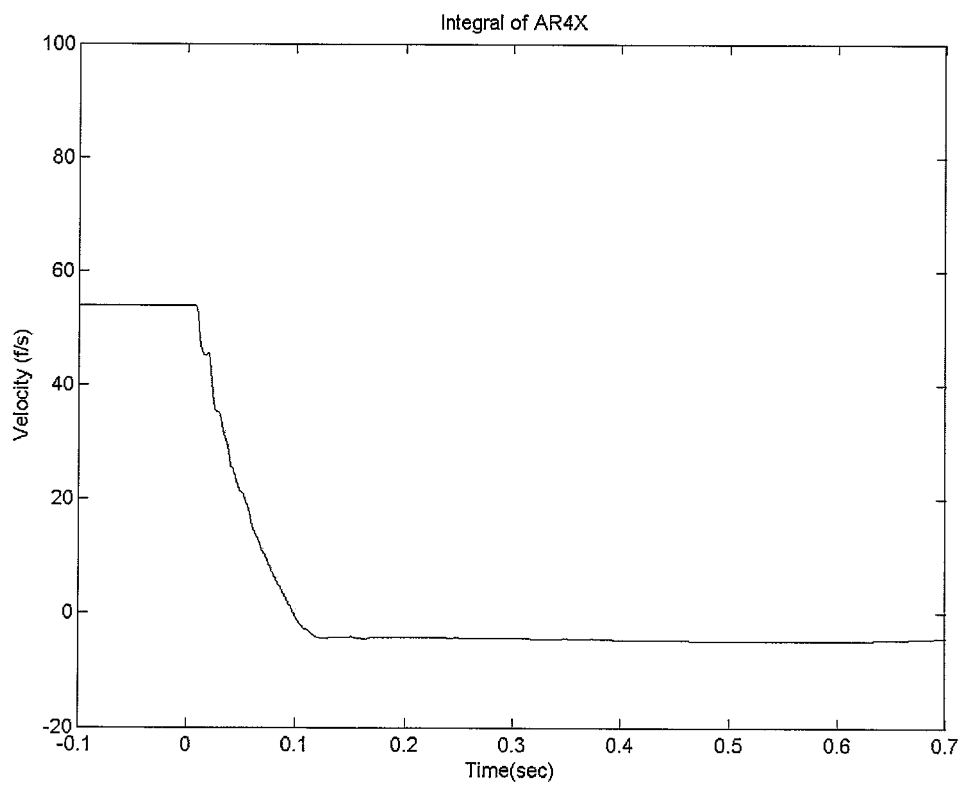


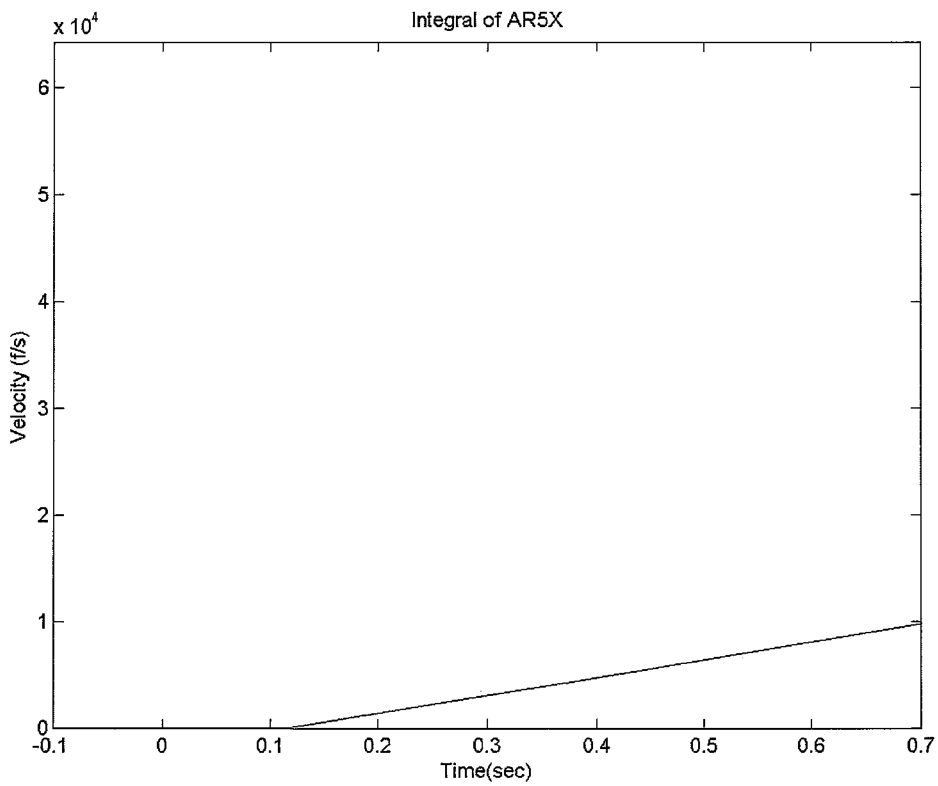
Integral of AR1X
Velocity (f/s)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

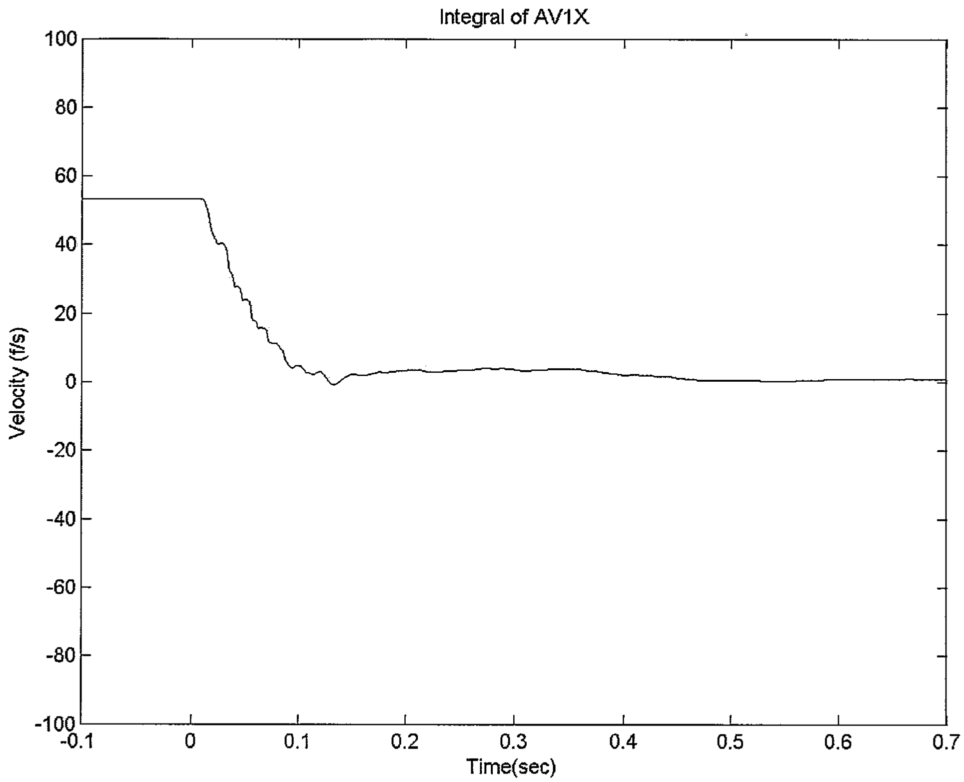


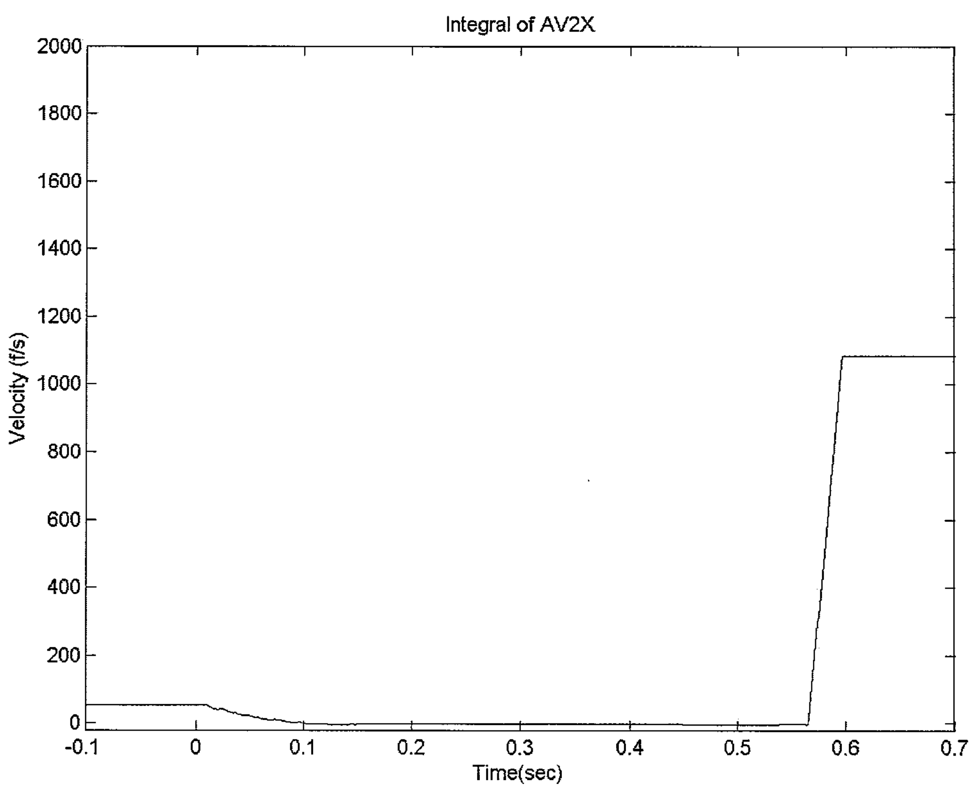
Integral of AR2X
Velocity (f/s)
Time(sec)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Integral of AR3X
Velocity (f/s)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


Integral of AR4X
Velocity (f/s)
100
80
60
40
20
0
-20
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


Integral of AR5X
x 10^4
6
5
4
3
2
1
0
Velocity (f/s)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


Integral of AV1X
Velocity (f/s)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)


Integral of AV2X
Velocity (f/s)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)