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Aluminum Honeycomb Characteristics in Dynamic Crush Environments

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Vesta I. Bateman and Lloyd H. Swanson

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Aluminum Honeycomb Characteristics in Dynamic Crush Environments

Vesta I. Bateman
Lloyd H. Swanson
Engineering Sciences Center
Sandia National Laboratories
P. O. Box 5800
Albuquerque, NM 87185-0555

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Abstract

Fifteen aluminum honeycomb cubes (3 in.) have been crushed in the Mechanical Shock Laboratory's drop table testing machines. This report summarizes shock experiments with honeycomb densities of 22.1 pcf and 38.0 pcf and with crush weights of 45 lb, 168 lb, and 268 lb. The honeycomb samples were crushed in all three orientations, W, L, and T. Most of the experiments were conducted at an impact velocity of ≈ 40 fps, but higher velocities of up to 90 fps were used for selected experiments. Where possible, multiple experiments were conducted for a specific orientation and density of the honeycomb samples. All results are for Hexcel honeycomb except for one experiment with Alcore honeycomb and have been evaluated for validity. This report contains the raw acceleration data measured on the top of the drop table carriage, pictures of the crushed samples, and normalized force-displacement curves for all fifteen experiments. These data are not strictly valid for material characteristics in L and T orientations because the cross-sectional area of the honeycomb changed (split) during the crush. However, these are the best data available at this time. These dynamic crush data do suggest a significant increase in crush strength to 8000 psi (~ 25 -30% increase) over quasi-static values of ~ 6000 psi for the 38.0 pcf Hexcel Honeycomb in the T-orientation. An uncertainty analysis is included and estimates the error in these data.

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Aluminum Honeycomb Characteristics in Dynamic Crush Environments

Introduction

Sandia National Laboratories (SNL) designs and builds energy absorbing components that are capable of cushioning the impact of a structure in 150 fps head-on impact or a 73 fps (B61 Mod 3,4,10) and 90 fps (B61 Mod 7) slapdown environment. The certification of these energy absorbing components involves both impact experiments and finite element models. The models must be validated and verified so that they can be used to predict component performance and thereby reduce the number of expensive full-scale experiments that are performed. Additionally, the models are used to optimize the experiments by identifying the impact environments.

The honeycomb experiments presented in this report were conducted to aid in the modeling of an energy absorbing component that uses aluminum honeycomb. Fifteen aluminum honeycomb cubes (3 in.) have been crushed in the Mechanical Shock Laboratory using drop table shock machine carriages as the crush weight. This report summarizes shock experiments with honeycomb densities of 22.1 pcf and 38.0 pcf and with crush weights of 45 lb, 168 lb, and 268 lb. The honeycomb samples were crushed in all three orientations, W, L, and T. Most of the experiments were conducted at an impact velocity of ≈ 40 fps, but higher velocities of up to 90 fps were used for selected experiments. Where possible, multiple experiments were conducted for a specific orientation and density of the honeycomb samples. All results are for Hexcel* honeycomb except for one experiment with Alcore* honeycomb and have been examined for validity. This report contains the raw acceleration data measured on the top of the drop table carriage, pictures of the crushed samples, and normalized force-displacement curves for all fifteen experiments. Although these data are not valid for material characteristics for L and T orientations because the cross-sectional area of the honeycomb changed during the crush, these are the best dynamic data available for honeycomb undergoing crush in a shock environment. An uncertainty analysis is included and estimates the error in these data.

Experimental Configuration

The general experimental configuration for eleven unconfined aluminum honeycomb crush experiments in 1997-98 and four experiments in 1999 is shown in Figure 1, and the experimental parameters are shown in Table I. The three orientations of W, L, and T for the honeycomb are shown in Figure 2. The honeycomb sample was placed on the reaction mass in the specified orientation. For the experiments in 1997-98, one each of

*Reference to a commercial product implies no endorsement by SNL or the Department of Energy or lack of suitable substitute.

Figure 1: Experimental Configuration for Unconfined Honeycomb Experiments with a Drop Table Shock Machine.

Figure 2: Definition of T, L, and W Orientations for Aluminum Honeycomb.

Table I: Aluminum Honeycomb Crush Experiment Parameters.

Experiment Number	Experiment Date	Crush Weight (lbs)	Density (pcf)	Honeycomb Orientation	GHI Velocity (fps)
002	1997-8	45	38.0	W	40.23
003	1997-8	45	38.0	L	39.85
004	1997-8	45	22.1	L	39.68
005	1997-8	45	22.1	W	39.63
025	1997-8	268	38.0	T	57.70
026	1997-8	168	22.1	T	90.00
027	1997-8	168	22.1	T	50.00
028	1997-8	268	38.0	T	53.12
029	1997-8	268	38.0	T	50.00
031	1997-8	168	22.1	T	50.00
037	1997-8	268	38.0*	T	51.13
003	1999	45	38.0	W	39.66
005	1999	45	38.0	L	39.72
006	1999	168	38.0	W	40.18
008	1999	168	38.0	L	40.11

* Test #37 is an Alcore sample.

the ENDEVCO 7270AM6-20K* Accelerometers were mounted on the drop table and the reaction mass. The honeycomb is crushed by the drop table carriage at a specified impact velocity. The impact velocity is calculated from the time it takes a precise length of steel to pass by two optical sensors as measured by the GHI* device. The integration of the carriage accelerometer provides a redundant velocity measurement and validation of the GHI measurement. These experiments are not a constant velocity crush of the honeycomb samples. The carriage slows down continuously during the crush.

In 1999, four experiments as shown in Table I were conducted with accelerometers that have a lower range than the ENDEVCO 7270AM6-20K* used in the 1997-98 experiments. One undamped, piezoresistive accelerometer, ENDEVCO 7270AM6-6K*, and one oil-damped, piezoelectric accelerometer, ENDEVCO 2262-1K*, were placed in the two locations of the drop table carriage and on the reaction mass. The redundant instrumentation for these four experiments allowed validation of the previous data taken in 1997-98. The two accelerometers used in 1999 are equally suited to this work.

A second experimental configuration for semiconfined honeycomb experiments with a punch and a drop table shock machine shown in Figure 3 was proposed and constructed. The honeycomb experimental matrix in Table II for the existing 38 pcf (6500 psi) Hexcel samples was chosen with the concurrence of those constructing a

*Reference to a commercial product implies no endorsement by SNL or the Department of Energy or lack of suitable substitute.

Figure 3: Semiconfined Honeycomb Experimental Configuration with Punch and Drop Table Shock Machine.

**Table II: Experimental Matrix for 38 pcf Hexcel Honeycomb
(3 by 3 by 3 in. Samples)**

<u>No. of Samples</u>	<u>Orientation</u>	<u>Purpose</u>
3	T and L	Experimental Configuration Confirmation
8	T	Compare results with Lu's Static Experiments
4	L	Requested by Terry Hinnerich for lateral model

constitutive model for the honeycomb. One experiment with the punch bolted to the bottom of the drop table shock machine was conducted at the maximum available impact velocity in the Area I Mechanical Shock Laboratory of 90 fps with an impact weight of 168 lb. The minimum crush weight available is 168 lb at this velocity. Since the honeycomb characteristics prior to lockup are needed, a two-in penetration depth was desired. Accelerometers were mounted on the carriage and the reaction mass to obtain data for calculation of force-displacement characteristics, and the GHI optical device measured impact velocity. The honeycomb sample was placed in the middle of the phenolic programmer in the T orientation. No valid data were obtained from this experimental configuration because the sample split upon impact. The data were examined visually but were not stored on the data acquisition system. It was concluded that this configuration is not useful to crush the honeycomb samples. Consequently, this experimental configuration was abandoned and the experiments proposed in Table II will be conducted with another experimental configuration.

Experimental Results

The pre-test and post-test dimensional measurements for the fifteen honeycomb crush experiments are shown in Table III. Excellent agreement between the redundant accelerometer measurements made in 1999 was obtained even though honeycomb crushes were performed with two substantially different crush weights for the W and L orientations. To obtain the correct honeycomb crush characteristics in the form of normalized force-displacement curves, the acceleration measurements on the reaction mass during honeycomb crush were used to remove reaction mass motion from the carriage acceleration response. Both acceleration time-histories were integrated over the entire time window recorded for each experiment. Most of the data were low-pass filtered with a cutoff frequency at 10 kHz prior to the integration, although some data were low-pass filtered with a lower cutoff frequency as noted on the raw acceleration plots in the appendices. The carriage velocity was corrected by subtracting out the reaction mass velocity. A correct crush distance was then obtained by integrating the corrected carriage velocity. The crush distance obtained from double integration of the acceleration data agreed with the physical measurements shown in Table III within 5% or less.

The reaction mass is made of steel and is substantially heavier than the aluminum carriage. The reaction mass starts to move during the honeycomb crush. By the time

**Table III: Aluminum Honeycomb Crush Experiment
Dimensional Measurements.**

Experiment Number	Honeycomb Orientation	Pre-Experiment Dimensions (in)			Post-Experiment Dimensions (in)		
		W	L	T	W	L	T
002	W	No pre-experiment dimensions Taken for these experiments			1.304	3.053	3.037
003	L				3.78	1.468	3.003
004	L				5.55	0.433	3.028
005	W				0.670	3.494	2.990
025	T	2.998	3.006	3.002	6.0	3.194	0.667
026	T	Maximum velocity demonstration for 22.1 pcf sample*.					
027	T	3.011	3.025	3.014	3.70	3.700	0.615
028	T	3.028	2.977	2.991	*	3.160	0.710
029	T	3.001	3.024	3.026	3.241	*	0.660
031	T	3.006	3.025	3.013	3.600	3.600	0.651
037	T	3.022	3.010	3.002	6.750	3.290	0.625
003	W	3.004	3.019	3.014	1.341	3.038	3.036
005	L	3.023	2.959	2.991	3.537	1.435	3.014
006	W	2.983	2.948	3.004	0.779	3.267	3.082
008	L	2.996	3.012	2.994	4.730	0.713	3.066

* Dimensional readings were not obtained due to either sample distortion or sample fragmentation.

lockup of the honeycomb has occurred, the carriage and the reaction mass are moving together. When the drop table and the reaction mass move together, the relative motion must be used to calculate the honeycomb crush characteristics, and the accelerometer measurement on the reaction mass is used to do this. The ratio of carriage mass to reaction mass is 10 for DT-66 drop table shock machine that has a 45 lb carriage. The ratio of carriage mass to reaction mass is 18 for DT-45 drop table shock machine that has a 168 lb carriage. The movement of the reaction mass was much later in the honeycomb crush for DT-45 than for DT-66 whose reaction mass started to move shortly after the crush was initiated. Consequently, better data are obtained with the higher mass ratio between the carriage or crush weight and the reaction mass because the reaction mass acts more like the desired rigid mass.

The honeycomb crush characteristics in the form of normalized force-displacement curves for individual experiments are shown in Appendices A and B for the 1997-98 experiments and the 1999 experiments, respectively. Post-test pictures of the honeycomb samples taken with a digital camera are shown in Appendices C and D for the 1997-98 experiments and the 1999 experiments, respectively. Finally, the wideband accelerometer data for each experiment are shown in Appendices E and F for the 1997-98 experiments and the 1999 experiments, respectively.

Composite plots of multiple experiments for a specific density and orientation have been made in Figures 4-9. Figures 4-6 are for the 22.1 pcf honeycomb in the three orientations, and Figures 7-9 are for the 38.0 pcf honeycomb in the three orientations. These data have been digitally filtered with a low-pass filter [1] whose cutoff frequency of 2000 Hz has been chosen to minimize the structural response in the data without compromising the dynamic response in the form of the rise-time of the stress time-history. The structural response is the first bending mode of the carriage at 7200 Hz. The cutoff frequency at 2000 Hz restricts the influence of the structural response to 10%. These data plots show the initiation of honeycomb lockup when the crush event is over and the reaction mass and carriage move together with no carriage rebound.

Uncertainty Analysis

The uncertainty in these measurements and results are attributed to two sources: the uncertainty in the accelerometer calibrations and the influence of the carriage structural response. The uncertainty in the GHI velocity measurement is 0.1% and is negligible in this analysis. The accelerometer and data acquisition uncertainty is monitored on a continual basis in the SNL Mechanical Shock Laboratory as required by the SNL Specification 9958003 [2]. These requirements include the performance of both the hardware (accelerometers, amplifiers, digitizers etc.) [2,3] and the software IMPAX that controls the data acquisition system through a computer [2,4,5]. The current data acquisition system and software meet these requirements within $\pm 0.5\%$, and documentation of these results is maintained in the Mechanical Shock Laboratory. Consequently, the only uncertainty in these measurements is the uncertainty in the accelerometer calibration, $\pm 5\%$ [6] and the influence of the carriage structural response of 10% [6]. These two uncertainties are considered random, so they may be combined in an uncertainty analysis with a 95% confidence level as [7,8]:

$$w_T = \sqrt{w_s^2 + w_{csr}^2} \quad (1)$$

where: w_T = total uncertainty,
 w_s = accelerometer calibration uncertainty 5%, and
 w_{csr} = carriage structural response uncertainty 10%.

The value of the total uncertainty, w_T , is $\pm 11\%$ and is typical for the measurements made in the SNL Mechanical Shock Laboratory.

Conclusions and Future Work

Of the fifteen honeycomb crush experiments documented in this report, seven experiments were in the T orientation. Since this orientation is the most important for the model of the honeycomb, future experiments should concentrate on the T orientation. The 22.1 pcf density honeycomb has approximately the same performance

in the W and L orientations. However, the 38.0 pcf density honeycomb has better performance in the L orientation compared to the W orientation because of the additional stiffener through the middle of each L cell. The differences in the honeycomb performance (lockup) in Figure 6 are attributed to the two different impact velocities.

These data show dynamic enhancement in the performance of the honeycomb in a dynamic crush environment or impact shock environment and are consistent with current MAVEN results. The dynamic enhancement is the increase in the T orientation strength over the nominal value of 6500 psi for 38.0 pcf and 3800 psi for the 22.1 pcf. These data are not strictly valid for material characteristics in L and T orientations because the cross-sectional area of the honeycomb changed (split) during the crush. However, these are the best data available at this time. These dynamic crush data do suggest a significant increase in crush strength to 8000 psi (~ 25-30% increase) over quasi-static values [9] of ~ 6000 psi shown in Figure 10 for the 38.0 pcf Hexcel Honeycomb in the T-orientation.

Figure 4: Experiment 5 (98): Hexcel, 22.1 pcf, W Orientation and 40 fps.

Figure 5: Experiment 4 (98): Hexcel, 22.1 pcf, L Orientation and 40 fps.

Figure 6: Experiments 26,27&31 (98): Hexcel Honeycomb, 22.1 pcf, T Orientation, 168 lb Crush Weight.

Figure 7: Experiments 2 (98) 3&6 (99): Hexcel, 38.0 pcf, W Orientation and 40 fps.

Figure 8: Experiments 3 (98) 5&8 (99): Hexcel, 38.0 pcf, L Orientation and 40 fps.

**Figure 9: Experiments 25,28,29&37: Honeycomb, 38.0 pcf,
T Orientation, 268 lb Crush Weight.**

Figure 10: Quasi-Static Characteristics for Hexcel 38.0 pcf Aluminum Honeycomb in T Orientation Quasi-Static Characteristics [9].

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Appendix A

**Normalized Honeycomb Crush Characteristics
(1997-98)**

Experiment 4: Hexcel Honeycomb, 22.1 pcf, L orientation, and 40 fps.

Experiment 5: Hexcel Honeycomb, 22.1 pcf, W orientation, and 40 fps.

Experiment 25: Hexcel Honeycomb, 38.0 pcf, T orientation, and 58 fps.

Experiment 26: Hexcel Honeycomb, 22.1 pcf, T orientation, and 90 fps.

Experiment 27: Hexcel Honeycomb, 22.1 pcf, T orientation, and 50 fps.

Experiment 28: Hexcel Honeycomb, 38.0 pcf, T orientation, and 53 fps.

Experiment 29: Hexcel Honeycomb, 38.0 pcf, T orientation, and 50 fps.

Experiment 31: Hexcel Honeycomb, 22.1 pcf, T orientation, and 42 fps.

Experiment 37: Alcore Honeycomb, 35.0 pcf, T orientation, and 51 fps.

Appendix B

**Normalized Honeycomb Crush Characteristics
(1999)**

Experiment 3 with DT-66: Hexcel Honeycomb, 38 pcf, W orientation, and 40 fps.

Experiment 5 with DT-66: Hexcel Honeycomb, 38 pcf, L orientation, and 40 fps.

Experiment 6 with DT-45: Hexcel Honeycomb, 38 pcf, W orientation, and 40 fps.

Experiment 8 with DT-45: Hexcel Honeycomb, 38 pcf, L orientation, and 40 fps.

Appendix C

Pictures of Crushed Honeycomb for Experiments 1997-98

#2 - 38.0 PCF Material
W axis test
45 pound carriage
40.23 FPS impact velocity

#2 - 38.0 PCF Material
W axis test
45 pound carriage
40.23 FPS impact velocity

#3 -38.0 PCF Material
L axis test
45 pound carriage
39.85 FPS impact velocity

#3 -38.0 PCF Material
L axis test
45 pound carriage
39.85 FPS impact velocity

#4 -22.1 PCF Material
L axis test
45 pound carriage
39.68 FPS impact velocity

#4 -22.1 PCF Material

L axis test

45 pound carriage

39.68 FPS impact velocity

#5 -22.1 PCF Material
W axis test
45 pound carriage
39.63 FPS impact velocity

#5 -22.1 PCF Material
W axis test
45 pound carriage
39.63 FPS impact velocity

#25 - 38.0 PCF Material
T axis test
268 pound carriage
57.70 FPS impact velocity

#25 - 38.0 PCF Material
T axis test
268 pound carriage
57.70 FPS impact velocity

#26 - 22.1 PCF Material
T axis test
168 pound carriage
about 90 FPS impact velocity

#27 - 22.1 PCF Material
T axis test
168 pound carriage
50.00 FPS impact velocity

#27 - 22.1 PCF Material
T axis test
168 pound carriage
50.00 FPS impact velocity

#28 - 38.0 PCF Material
T axis test
168 pound carriage
53.12 FPS impact velocity

#28 - 38.0 PCF Material
T axis test
168 pound carriage
53.12 FPS impact velocity

#29 - 38.0 PCF Material

T direction

268 lb. carriage weight

50 FPS carriage velocity

#29 - 38.0 PCF Material

T direction

268 lb. carriage weight

50 FPS carriage velocity

#31 - 22.1 PCF Material

T-direction

168 lb. carriage weight

50 FPS carriage velocity

#31 - 22.1 PCF Material
T direction
168 lb. carriage weight
50 FPS carriage velocity

#37 - 38.0 PCF Material - Alcore
T axis test
268 pound carriage
51.13 FPS impact velocity

#37 - 38.0 PCF Material - Alcore
T axis test
268 pound carriage
51.13 FPS impact velocity

Appendix D

Pictures of Crushed Honeycomb for Experiments 1999

4/16/99 - #3 - 38.0 PCF Material
W Axis Test
45 pound carriage
39.66 FPS impact velocity

4/16/99 - #3 - 38.0 PCIF Material
W Axis Test
45 pound carriage
39.66 FPS impact velocity

4/16/99 - #5 - 38.0 PCIK Material
L Axis Test
45 pound carriage
39.72 FPS impact velocity

4/16/99 - #5 - 38.0 PCF Material
L Axis Test
45 pound carriage
39.72 FPS impact velocity

4/16/99 - #6 - 38.0 PCF Material
W Axis Test
168 pound carriage
40.18 FPS impact velocity

4/16/99 - #6 - 38.0 PCF Material
W Axis Test
168 pound carriage
40.18 FPS impact velocity

4/16/99 - #8 - 38.0 PCF Material
LAxis Test
168 pound carriage
40.11 FPS impact velocity

4/16/99 - #8 - 38.0 PCF Material

L.Axis Test

168 pound carriage

40.11 FPS impact velocity

Appendix E

Raw Accelerometer Data Measured on the Drop Table Carriage and the Reaction Mass (1997-98)

Test Title: Honeycomb Crush (38.0 pcf W axis) Test No. 002 Case No: 8758.231 Test Date: 03-14-97 12:28
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
Transducer Serial No: AAHA9 SR: 2.00000E+005 Transducer Location: On reaction mas
Pulse Parameters: M.F.A. 118.1160 g TT: 0.0750 ms TR: 0.0300 ms TF: 0.0300 ms TP: 0.0400 ms

Test Title: Honeycomb Crush (38.0 pcf L axis) Test No. 003 Case No: 8758.231 Test Date: 03-14-97 12:36
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
Transducer Serial No: AFFD9 SR: 2.000000E+005 Transducer Location: On Carriage
Pulse Parameters: M.F.A. 510.2930 g TT: 0.0850 ms TR: 0.0350 ms TP: 0.0400 ms

Test Title: Honeycomb Crush (38.0 pcf L axis) Test No. 003 Case No: 8758.231 Test Date: 03-14-97 12:36
 DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
 Transducer Serial No: AAHA9 SR: 2.000000E+005 Transducer Location: On reaction mas
 Pulse Parameters: M.F.A. 320.7006 g TT: 0.0750 ms TR: 0.0300 ms TF: 0.0250 ms TP: 0.0400 ms

Test Title: Honeycomb Crush (22.1 pcf L axis)

Case No: 8758.231

Test No. 004

Test Date: 03-14-97 12:44

DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000

Transducer Serial No: AFD9 SR: 2.000000E+005 Transducer Location: On Carriage

Pulse Parameters: M.F.A. 1478.6774 g TT: 1.5850 ms TR: 1.1350 ms TF: 0.2150 ms TP: 1.2750 ms

Test Title: Honeycomb Crush (22.1 pcf L axis) Test No. 004 Case No: 8758.231 Test Date: 03-14-97 12:44
 DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
 Transducer Serial No: AAHA9 SR: 2.000000E+005 Transducer Location: On reaction mas
 Pulse Parameters: M.F.A. -145.8866 g TT: 0.8350 ms TR: 0.4700 ms TF: 0.3300 ms TP: 0.4850 ms

Test Title: Honeycomb Crush (22.1 pcf W axis) Test No. 005 Case No: 8758.231 Test Date: 03-14-97 12:50
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
Transducer Serial No: AFFD9 SR: 2.000000E+005 Transducer Location: On Carriage
Pulse Parameters: M.F.A. 1036.9082 g TT: 1.8400 ms TR: 1.1700 ms TF: 0.3250 ms TP: 1.3900 ms

Test Title: Honeycomb Crush (22.1 pcf W axis) Test No. 005 Case No: 8758.231 Test Date: 03-14-97 12:50
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
Transducer Serial No: AAHA9 SR: 2.000000E+005 Transducer Location: On reaction mas
Pulse Parameters: M.F.A. -83.6963 g TT: 2.0850 ms TR: 1.3300 ms TF: 0.5350 ms TP: 1.4350 ms

Test Title: Honeycomb Crush (38.0 pcf T axis) Test No. 025 Case No: 8758.231 Test Date: 04-07-97 14:55
 DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
 Transducer Serial No: AFFD9 SR: 2.000000E+005 Transducer Location: On Carriage 1/4 Felt
 Pulse Parameters: M.F.A. 800.4531 g TT: 0.0900 ms TR: 0.0350 ms TF: 0.0400 ms TP: 0.0400 ms

Test Title: Honeycomb Crush (38.0 pcf T axis) Test No. 025 Case No: 8758.231 Test Date: 04-07-97 14:55
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
Transducer Serial No: AAHA9 SR: 2.000000E+005 Transducer Location: On react mass 1/4 Felt
Pulse Parameters: M.F.A. 275.0678 g TT: 0.0650 ms TR: 0.0250 ms TF: 0.0250 ms TP: 0.0300 ms

Test Title: Honeycomb Crush (22.1 pcf T axis)		Test No. 026	Case No: 8758.231	Test Date: 04-07-97 15:39
DAS Channel: CH01		LP FILTERS: Analog (Hz) = 100 KHz	Digital (Hz) = 10000.000	
Transducer Serial No: AFFD9		SR: 2.000000E+005	Transducer Location: On Carriage	1/4 Felt
Pulse Parameters: M.F.A. 3110.5671 g		TT: 1.2350 ms	TR: 0.5350 ms	TP: 0.6700 ms

Test Title: Honeycomb Crush (22.1 pcf T axis) Test No. 026 Case No: 8758.231 Test Date: 04-07-97 15:39
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 10000.000
Transducer Serial No: AAHA9 SR: 2.000000E+005 Transducer Location: On react mass 1/4 Felt
Pulse Parameters: M.F.A. -363.7765 g TT: 0.3650 ms TR: 0.0350 ms TF: 0.3100 ms TP: 0.0450 ms

Test Title: Honeycomb Crush (22.1 pcf T axis) Test No. 027 Case No: 8758.231 Test Date: 04-22-97 14:40
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 5000.000
Transducer Serial No: AFD9 SR: 2.000000E+005 Transducer Location: On Carriage 1/4 Felt
Pulse Parameters: M.F.A. 619.4363 g TT: 7.6700 ms TR: 6.5800 ms TF: 0.5250 ms TP: 6.9150 ms

Test Title: Honeycomb Crush (22.1 pcf T axis) Test No. 027 Case No: 8758.231 Test Date: 04-22-97 14:40
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 5000.000
Transducer Serial No: AAHA9 SR: 2.000000E+005 Transducer Location: On react mass 1/4 Felt
Pulse Parameters: M.F.A. -47.1912 g TT: 0.7450 ms TR: 0.0900 ms TF: 0.6000 ms TP: 0.1150 ms

Test Title: Honeycomb Crush (38.0 pcf T axis) Test No. 028 Case No: 8758.231 Test Date: 04-22-97 15:15
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 5000.000
Transducer Serial No: AAHA9 SR: 2.000000E+005 Transducer Location: On react mass 1/4 Felt
Pulse Parameters: M.F.A. -84.3759 g TT: 1.1850 ms TR: 0.0650 ms TF: 0.2600 ms TP: 0.0850 ms

Test Title: Honeycomb Crush (38.0 pcf T axis) Test No. 029 Case No: 8758.231 Test Date: 04-30-97 10:31
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 5000.000
Transducer Serial No: AFFD9 SR: 2.000000E+005 Transducer Location: On Carriage 1/4 Felt
Pulse Parameters: M.F.A. 600.2917 g TT: 3.4050 ms TR: 2.2550 ms TF: 0.5550 ms TP: 2.6200 ms

Test Title: Honeycomb Crush (38.0 pcf T axis) Test No. 029 Case No: 8758.231 Test Date: 04-30-97 10:31
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 5000.000
Transducer Serial No: AG5M0 SR: 2.000000E+005 Transducer Location: On react mass 1/4 Felt
Pulse Parameters: M.F.A. -87.5811 g TT: 0.7550 ms TR: 0.0850 ms TF: 0.6150 ms TP: 0.1150 ms

Test Title: Honeycomb Crush (22.1 pcf T axis) Test No. 031 Case No: 8758.231 Test Date: 04-30-97 13:17
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 5000.000
Transducer Serial No: AFFD9 SR: 2.000000E+005 Transducer Location: On Carriage 1/4 Felt
Pulse Parameters: M.F.A. 581.7064 g TT: 5.9900 ms TR: 4.9850 ms TF: 0.4250 ms TP: 5.3450 ms

Test Title: Honeycomb Crush (22.1 pcf T axis) Case No: 8758.231 Test Date: 04-30-97 13:17
 DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 5000.000
 Transducer Serial No: AG5M0 SR: 2.000000E+005 Transducer Location: On react mass 1/4 Felt
 Pulse Parameters: M.F.A. -56.4908 g TT: 0.1700 ms TR: 0.0650 ms TP: 0.0850 ms

Test Title: Honeycomb Crush (38.0 pcf T axis ALCORE) Test No. 037 Case No: None Test Date: 09-23-98 10:47
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 3000.000
Transducer Serial No: B02AF SR: 2.000000E+005 Transducer Location: On Carriage 1/4 Felt
Pulse Parameters: M.F.A. 512.0696 g TT: 7.3500 ms TR: 6.0950 ms TF: 0.5000 ms TP: 6.6300 ms

Test Title: Honeycomb Crush (38.0 pcf T axis ALCORE) Test No. 037 Case No: None Test Date: 09-23-98 10:47
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 KHz Digital (Hz) = 3000.000
Transducer Serial No: AR36F SR: 2.000000E+005 Transducer Location: On react mass 1/4 Felt
Pulse Parameters: M.F.A. -47.6351 g TT: 2.7500 ms TR: 1.7200 ms TF: 0.4600 ms TP: 1.8000 ms

Appendix F

Raw Accelerometer Data Measured on the Drop Table Carriage and the Reaction Mass (1999)

Test Title: Honeycomb Tests, 38.0 pcf material, W axis Test No. 003 Case No: None Test Date: 04-16-99 09:04
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100KHZ Digital (Hz) = 10000.000
Transducer Serial No: F10388 SR: 1.000000E+005 Transducer Location: Carriage
Pulse Parameters: M.F.A. 416.3850 g TT: 6.1100 ms TR: 4.4400 ms TF: 0.7200 ms TP: 5.0800 ms

Test Title: Honeycomb Tests, 38.0 pcf material, W axis Test No. 003 Case No: None Test Date: 04-16-99 09:04
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
Transducer Serial No: F10380 SR: 1.000000E+005 Transducer Location: Reaction Mass
Pulse Parameters: M.F.A. -57.4955 g TT: 2.6000 ms TR: 1.4000 ms TF: 0.6700 ms TP: 1.4100 ms

Test Title: Honeycomb Tests, 38.0 pcf material, W axis Test No. 003 Case No: None Test Date: 04-16-99 09:04
 DAS Channel: CH03 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
 Transducer Serial No: PE90 SR: 1.000000E+005 Transducer Location: Carriage
 Pulse Parameters: M.F.A. 429.5920 g TT: 6.1300 ms TR: 4.4700 ms TF: 0.7500 ms TP: 5.0600 ms

Test Title: Honeycomb Tests, 38.0 pcf material, W axis Test No. 003 Case No: None Test Date: 04-16-99 09:04
DAS Channel: CH04 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
Transducer Serial No: LN34 SR: 1.000000E+005 Transducer Location: Reaction Mass
Pulse Parameters: M.F.A. -48.1037 g TT: 3.1200 ms TR: 0.6700 ms TF: 1.3200 ms TP: 0.8000 ms

Test Title: Honeycomb Tests, 38.0 pcf material, L axis Test No. 005 Case No: None Test Date: 04-16-99 10:14
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100KHZ Digital (Hz) = 10000.000
Transducer Serial No: F10388 SR: 1.000000E+005 Transducer Location: Carriage
Pulse Parameters: M.F.A. 545.7189 g TT: 0.1100 ms TR: 0.0600 ms TP: 0.0700 ms

Test Title: Honeycomb Tests, 38.0 pcf material, L axis Test No. 005 Case No: None Test Date: 04-16-99 10:14
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
Transducer Serial No: F10380 SR: 1.000000E+005 Transducer Location: Reaction Mass
Pulse Parameters: M.F.A. -237.7966 g TT: 0.1200 ms TR: 0.0300 ms TF: 0.0800 ms TP: 0.0300 ms

Test Title: Honeycomb Tests, 38.0 pcf material, L axis Test No. 005 Case No: None Test Date: 04-16-99 10:14
DAS Channel: CH03 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
Transducer Serial No: PE90 SR: 1.000000E+005 Transducer Location: Carriage
Pulse Parameters: M.F.A. 389.0406 g TT: 0.8200 ms TR: 0.0600 ms TP: 0.0700 ms

Test Title: Honeycomb Tests, 38.0 pcf material, L axis

Case No: 005

Test Date: 04-16-99 10:14

DAS Channel: CH04 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000

Transducer Serial No: LN34 SR: 1.000000E+005 Transducer Location: Reaction Mass

TP: 0.0900 ms

TR: 0.0900 ms

TT: 0.1800 ms

Pulse Parameters: M.F.A. -146.4386 g

Test Title: Honeycomb Tests, 38.0 pcf material, W axis Test No. 006 Case No: None Test Date: 04-16-99 14:16
DAS Channel: CH01 LP FILTERS: Analog (Hz) = 100KHZ Digital (Hz) = 10000.000
Transducer Serial No: F10388 SR: 1.000000E+005 Transducer Location: Carriage
Pulse Parameters: M.F.A. 1522.9739 g TT: 1.8500 ms TR: 1.2300 ms TF: 0.3500 ms TP: 1.4200 ms

Test Date: 04-16-99 14:16

Case No: None

Test Title: Honeycomb Tests, 38.0 pcf material, W axis

Test No. 006

DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000

Transducer Serial No: F10380 SR: 1.000000E+005

Transducer Location: Reaction Mass

Pulse Parameters: M.F.A. -96.3246 g TT: 1.4800 ms TR: 0.9400 ms TF: 0.3000 ms TP: 1.0800 ms

Test Title: Honeycomb Tests, 38.0 pcf material, W axis Test No. 006 Case No: None Test Date: 04-16-99 14:16
 DAS Channel: CH03 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
 Transducer Serial No: PE90 SR: 1.000000E+005 Transducer Location: Carriage
 Pulse Parameters: M.F.A. 1026.1245 g TT: 2.3700 ms TR: 1.4800 ms TF: 0.2800 ms TP: 2.0400 ms

Test Title: Honeycomb Tests, 38.0 pcf material, W axis Test No. 006 Case No: None Test Date: 04-16-99 14:16
DAS Channel: CH04 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
Transducer Serial No: LN34 SR: 1.000000E+005 Transducer Location: Reaction Mass
Pulse Parameters: M.F.A. -98.1236 g TT: 1.5800 ms TR: 1.0400 ms TF: 0.3100 ms TP: 1.1900 ms

Test Title: Honeycomb Tests, 38.0 pcf material, L axis Test No. 008 Case No: None Test Date: 04-16-99 14:39
DAS Channel: CH02 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
Transducer Serial No: F10380 SR: 1.000000E+005 Transducer Location: Reaction Mass
Pulse Parameters: M.F.A. 123.5079 g TT: 0.0600 ms TR: 0.0300 ms TF: 0.0300 ms TP: 0.0300 ms

Test Title: Honeycomb Tests, 38.0 pcf material, L axis Test No. 008 Case No: None Test Date: 04-16-99 14:39
 DAS Channel: CH03 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000
 Transducer Serial No: PE90 SR: 1.000000E+005 Transducer Location: Carriage
 Pulse Parameters: M.F.A. 1024.8706 g TT: 2.2400 ms TR: 1.3900 ms TF: 0.3500 ms TP: 1.8400 ms

Test Date: 04-16-99 14:39

Case No: 008

Test Title: Honeycomb Tests, 38.0 pcf material, L axis

DAS Channel: CH04 LP FILTERS: Analog (Hz) = 100 kHz Digital (Hz) = 10000.000

Transducer Serial No: LN34 SR: 1.000000E+005 Transducer Location: Reaction Mass

TP: 0.8500 ms

TF: 0.3200 ms

TR: 0.6800 ms

TT: 1.1800 ms

Pulse Parameters: M.F.A. -95.5125 g

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