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Comparison of AC and Original Formulation Confor™ Foam Performance in Civil Aircraft Vertical Impact Tests

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16. Abstract

Rate sensitive foams are often used in aircraft seat designs; recently, the formulation of one of the more common types of foam, Confor™, was changed. The previous Standard version came in four stiffness levels, which all met aircraft flammability requirements. The new version still has four stiffness levels; however, each type will consist of two formulations, one designated Confor™ M and one designated Confor™ AC. The Federal Aviation Administration's Civil Aerospace Medical Institute (CAMI) conducted testing to determine whether occupant injury risk during vertical impacts would be affected by substitution of the AC material in place of the original material in seat bottom cushions incorporated in dynamically qualified seats. A combination of original Confor™ foams obtained from stock at CAMI and the reformulated aerospace Confor™ supplied by Skandia, Inc., were dynamically tested on a rigid seat. The anthropomorphic test dummy used was the 50th percentile male FAA Hybrid III. In addition to lumbar loads, occupant kinematics, as well as seat pan loads and floor loads were gathered.

Confor™ foam comes in four different degrees of stiffness and is color-coded to avoid confusion. The two mid-stiffness foams, CF-42 (pink) and CF-45 (blue), were selected for this evaluation because they are the most commonly used types in aviation. The Confor™ original and AC formulation foams were evaluated at two test severities and two thicknesses. Due to limited material availability, only one test configuration was repeated. The 4-inch thick, AC formulation pink foam was tested three times at 19 G, producing a lumbar load range of 25 lb.

The 4-inch buildup blue Confor™ foam produced a difference in the normalized lumbar load of 14 lb more for the AC version at 14 G and 44 lb less for the AC at 19 G. The 4-inch buildup pink Confor™ foam produced a difference in the normalized lumbar load of approximately 53 lb more for the AC version at 14 G and 190 lb more for the AC at 19 G. The largest difference in peak lumbar load produced by the AC version was 11% greater than the original version. If some level of production variability is assumed, then these values suggest that there may not be a significant difference between the impact performance of the original and AC formulation for aircraft bottom seat cushion applications.

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Comparison of AC and Original Formulation Confor™ Foam Performance in Civil Aircraft Vertical Impact Tests

BACKGROUND

In a vertical impact, the seat bottom cushion plays a vital role in controlling the load transferred to the occupant's spine. The Federal Aviation Administration (FAA) has standards and regulations in place to protect occupants in the event of a crash. Dynamic testing is required by these standards in order to substantiate the safety of seating systems. One of the two dynamic tests required is a primarily vertical impact of 30° off vertical. In this test, the principal measurement is the compressive load in the lumbar spinal column, which has a regulatory limit of 1500 lb [1].

One commonly used type of foam, well suited to this application due to its rate sensitive qualities, is Confor™. This type of foam has been used in aircraft seat designs for many years; however, a recent product bulletin announced that the original line of Standard Confor™ is being replaced with two updated versions [2]. This change was necessary to comply with restrictions on the use of certain fire retardant chemicals used in the original foam's formulation. The previous Standard version came in four stiffness levels, which all met aircraft flammability requirements. The AC version still has four stiffness levels; however, each type will consist of two formulations, one designated Confor™ M and one designated Confor™ AC. These still have the loading rate sensitivity and slow recovery attributes as the previous foams, however, only the Confor™ AC is designed to meet the flammability requirements for use in aviation seating systems. The effect on lumbar load of substituting this AC foam in seating systems qualified with the original foam is unknown. This could affect seats being currently produced as well as spare cushions for seats in service. This unknown prompted testing to compare the original and AC formulations in order to quantify the potential impact on both new seats entering service and the continued safety of seats currently in the fleet.

METHODS

To compare the dynamic performance of the AC and original Confor™ formulations, a series of 18 sled tests were carried out on the acceleration servo-sled at the Civil Aerospace Medical Institute (CAMI).

Test Device

The Anthropomorphic Test Device (ATD) used to assess injury risk was a 50th percentile male-sized FAA Hybrid III. This ATD differs from the standard Hybrid III used in automotive testing because it has been modified to better emulate the more upright posture of an occupant in an airliner seat and provide kinematic and vertical load response equivalent to the Hybrid II [3]. The modification consists of several Hybrid II parts substituted into the structure including the lumbar spine, abdominal insert, chest jacket, and upper leg bone (Figure 1). The Hybrid II or an equivalent, such as the FAA Hybrid III, is currently required for certification tests of aviation seats. The FAA Hybrid III was selected for this project because its pelvis is manufactured to tighter dimensional tolerances than the Hybrid II, having a vertical height tolerance of ±0.07 inch versus ±0.2 inch for the Hybrid II. The same ATD was used for all tests in this project to further maximize repeatability.

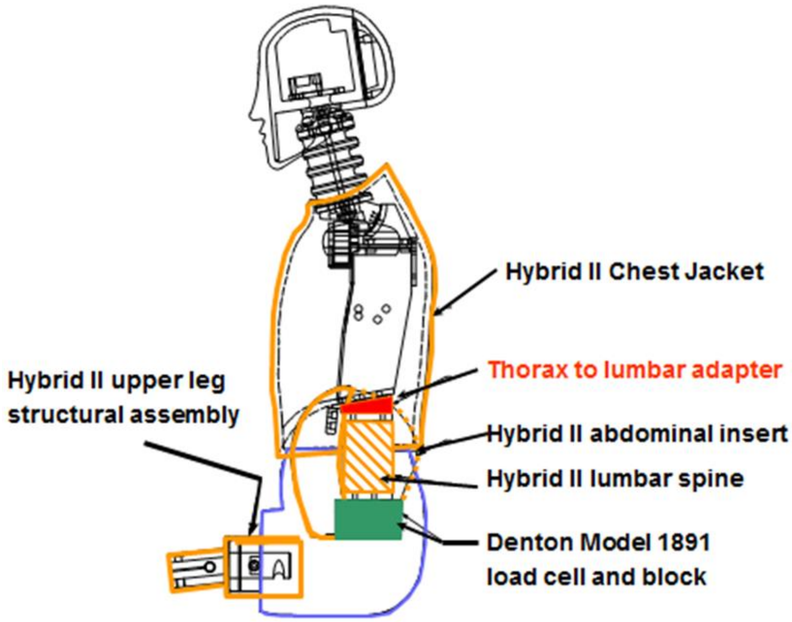

Figure 1. FAA Hybrid III; Orange Outlined Parts are Hybrid II

ATD Seating

To minimize the effect of seat frame flexibility on the test results, a rigid seat pitched up at a 60° angle was used to compare the different foams. The nominal upright ATD seated position (1-G position) was determined with respect to the seat cushion for each test article. To facilitate making this measurement, a surrogate wooden seat was fabricated with geometry, pan, and back angles identical to the rigid test seat (Figure 2).

For this measurement, the ATD was seated in accordance with a procedure developed at CAMI that results in a very consistent fore/aft position and initial pelvis angle [4]. This procedure involves suspending the ATD above the seat cushion just enough to insert a flat hand (approximately 1 inch) between the bottom of the pelvis and the cushion. A rigid bar is then inserted under the thighs just aft of the knees and used to elevate them slightly so as not to interfere with the ATD self-aligning. A force gage is used to press on the sternum of the ATD with approximately 20 lb of force while the ATD is lowered into full contact with the seating surface. The ATD is rocked from side-to-side and allowed to sit for 5 minutes in order to fully settle into the seat. This settling time is necessary for any slow recovery type foam to fully contour to the pelvis or buttocks of the ATD.

A three dimensional measuring machine was used to record the ATD head center of gravity photometric target, as well as the hip point and vertical pelvis targets. These measurements were used to derive the torso and pelvis angle. The hip point, or H-Point, lies on a line passing through the center of both hip ball/socket joints of the ATD. For these tests, target markers centered on this line were placed on the surface of the pelvis. The origin selected for the seating was the intersection of the rigid seat pan and seat back, which could be easily located on both the rigid test seat and the wooden surrogate.

Figure 2. FAA Hybrid III on Wooden 1 G Seating Fixture

The 1-G position data were then used to place the ATD in the correct fore-aft and vertical position in the pitched up rigid seat, with tolerances of ± 0.1 inch for the pelvis hip point, ± 1° for the pelvis angle, and ± 2° for the torso angle. Achieving this initial position required insertion of a cloth covered closed cell foam shim behind the ATD to maintain the fore-aft position and significant tension in the lap belt to maintain the vertical position. Note that in some tests, this tolerance on position was exceeded somewhat. This was due to the stress-relieving properties of this type of cushion foam, which made it very difficult to achieve and maintain an exact pelvis position.

Test Set Up

To evaluate occupant response at multiple loading rates, triangular shaped impact pulses with peak G of 14 G and 19 G were chosen (Figure 3). These test severities correspond to the combined horizontal/vertical tests specified in 14 CFR 25.562 and 23.562 [1]. A rigid seat test fixture with its horizontal (aircraft longitudinal) axis pitched up 60° with respect to the sled horizontal was used in order to eliminate as much variability as possible in the test set up (Figure 4). This seat had a seat back with an angle of 13° with respect to the aircraft vertical and a flat seat pan with an angle of 5° with respect to the horizontal. The seat pan was 16 inches wide and 15.5 inches long from the front edge to the intersection of the pan and back planes. The simulated floor was adjusted so that the distance between the H-Point and the center of the ankle was the same as the 1-G seated position, approximately 13 inches.

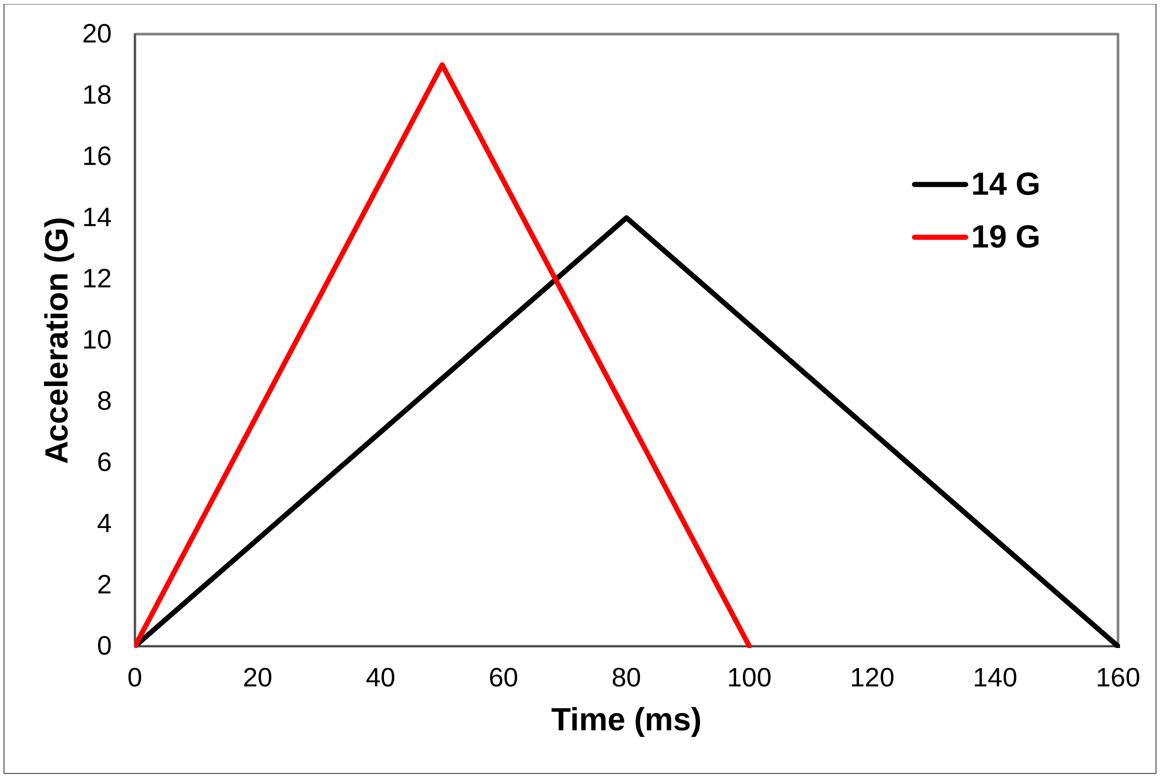

Figure 3. Ideal 14 and 19 G acceleration pulses

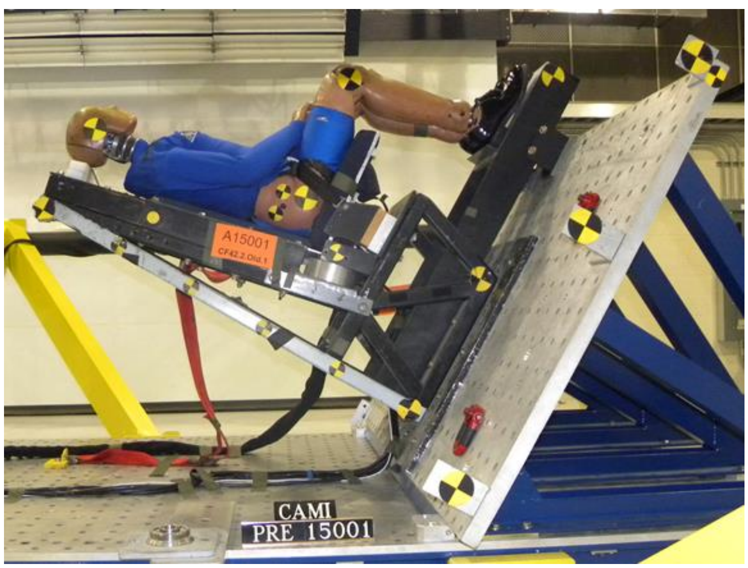

Figure 4. Rigid Seat Pitched up at 60°

Instrumentation

Electronic instrumentation. The ATD and rigid seat were instrumented as shown in Table 1. For this project, the seat pan and foot rest were instrumented with load cells to evaluate the manner in which the ATD loads into the rigid seat. The test data were gathered and filtered per the requirements of SAE J211-1 [5]. The sign convention of the recorded signals conformed to SAE J1733 [6].

Table 1. Instrumentation List

Ch. Number	Description	Filter Class	Range	Units
1	Sled Acceleration	60	25	G
2	Aux Sled Acceleration	60	25	G
4	Foot Rest Plate Acceleration	60	25	G
5	Lumbar Fx	600	3000	lb
6	Lumbar Fy	600	3000	lb
7	Lumbar Fz	600	5000	lb
8	Lumbar Mx	600	10000	in-lb
9	Lumbar My	600	10000	in-lb
10	Lumbar Mz	600	4000	in-lb
21	Thorax Ax	600	2000	G
22	Thorax Ay	600	2000	G
23	Thorax Az	600	2000	G
24	Thorax Rx ARS12K	180	12000	Deg/Sec
25	Thorax Ry ARS12K	180	12000	Deg/Sec
26	Thorax Rz ARS12K	180	12000	Deg/Sec
27	Thoracic Fx	600	3000	lb
28	Thoracic Fy	600	3000	lb
29	Thoracic Fz	600	4500	lb
30	Thoracic Mx	600	5000	in-lb
31	Thoracic My	600	8000	in-lb
32	Pelvis Ax	600	500	G
33	Pelvis Ay	600	500	G
34	Pelvis Az	600	500	G
35	Pelvis Rx ARS12K	180	12000	Deg/Sec
36	Pelvis Ry ARS12K	180	12000	Deg/Sec
37	Pelvis Rz ARS12K	180	12000	Deg/Sec
51	Seat Pan Load Cell Fx	60	10000	lb
52	Seat Pan Load Cell Fy	60	10000	lb
53	Seat Pan Load Cell Fz	60	10000	lb
54	Seat Pan Load Cell Mx	600	25000	in-lb
55	Seat Pan Load Cell My	600	25000	in-lb
56	Seat Pan Load Cell Mz	600	25000	in-lb
57	Foot Rest Load Cell Fx	60	10000	lb
58	Foot Rest Load Cell Fy	60	10000	lb
59	Foot Rest Load Cell Fz	60	10000	lb

Video coverage. High-speed (1000 frames per second), high resolution (1024 x 768 pixels) color video was captured from each side by cameras aimed perpendicular to the sled. Targets were placed on the ATD at the head center of gravity, the side of the pelvis at the hip joint, two auxiliary hip point locations, and on a rigid plate mounted to the knee joint. Targets were also placed on rigid structure for scaling and for subtracting relative motion between the sled and the camera. The positions of selected targeted points were measured initially with a measuring arm and derived during the test from the videos using procedures complying with the requirements of SAE J211-2 [7]. The relative accuracy of the tracked point locations, calculated per SAE J211-2 in this test series, ranged from 0.01 inch to 0.08 inch from their actual location. One target of interest, the H-point target marker, tended to move with respect to the internal pelvis structure due to flexure of the external flesh in that area as loading was applied. For this reason, the H-point (structural) location was derived from the tracked locations of other target markers on the pelvis that did not move relative to the internal pelvis structure. The accuracy of this virtual point is related to the accuracy of the referenced targets and their relative locations to the virtual point. In this case, it ranged from 0.02 to 0.16 inch from the actual location.

Restraint

A standard 2-point lap belt was used to restrain the ATD as well as hold the ATD in the nominal 1-G seating position. The belt anchors were 5.18 inches forward and 0.11 inch above the pan/back intersection. This location is further forward than typical for aircraft seats, but was chosen to facilitate observation of pelvis motion and to provide a means to maintain the necessary initial ATD preload into the cushion.

Cushion

Confor™ foam comes in four different degrees of stiffness and is color coded to avoid confusion. The two mid-stiffness foams, CF-42 (pink) and CF-45 (blue), were selected for this evaluation because they are the most commonly used types in aviation seats (Figure 5). The original formulation foam materials, which are no longer produced, were supplied from CAMI stock. The AC formulation foams were supplied by the foam distributor, Skandia Inc. All test articles of a particular type were cut from the same roll of material to maximize consistency between the articles. The articles were 18 inches wide and 16 inches long. Each article was held to the rigid seat pan by a tight fitting cloth cover.

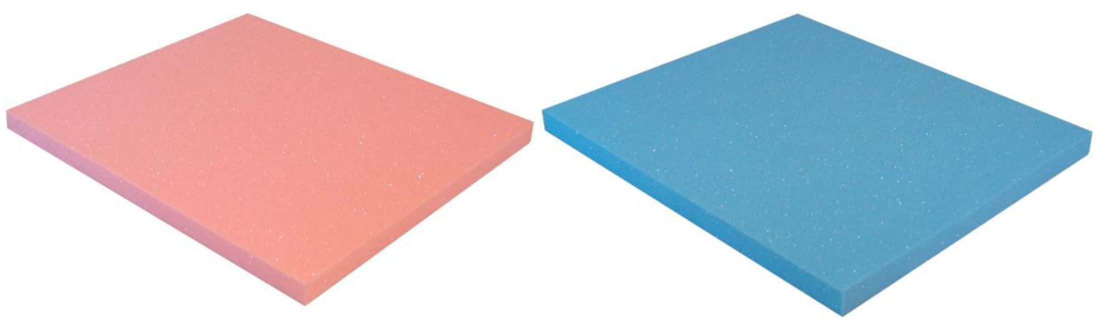

Figure 5. CF-42 (Pink) Left and CF-45 (Blue) Right Confor™ foams

Ten of the 18 tests were conducted using pink cushions, and of these 10, six were the AC foam in thickness of two and four inches, and four were the original formulation in thickness of two and four inches, see the test matrix in Table 2. The other eight tests were conducted with the blue foam, where each version and thickness was tested twice, once at each acceleration level. Due to scarcity of the original formulation foam, it was necessary to use some articles more than once. Since only the aft one-third of the cushion is loaded significantly by the ATD, turning the articles ensured that the area loaded had not been compressed during a previous test. Those articles were rotated 180° for the second test, rotated 90° and turned over for the third, and rotated 180° for the fourth.

Data Processing

The lumbar loads were gathered and filtered using CFC 600, and normalized to the test goal G-peak as allowed in AS8049B [8]. This procedure adjusts the recorded lumbar load value by multiplying it by the ratio of the goal acceleration divided by the measured peak acceleration. Seat pan and foot rest loads were tare corrected to eliminate the inertial effect of the fixture and internal load cell mass.

Test Matrix

Table 2 summarizes the variables evaluated for each test in this study. These include the cushion thickness in inches, cushion version (whether it is AC or original), and the goal peak G for the test, and the cushion color. Because of the efficiency of CAMI's servo sled system, it is possible to conduct simple tests like these in rapid succession. However, to provide the ATD elastomeric components sufficient time to recover to a nominal state, the ATD was situated such that no vertical load acted on the pelvis and spine for a minimum of 20 minutes between tests. Additionally, the time from when the ATD was positioned to match the 1-G seating to the time that the test was run was approximately 10 minutes, which allowed for the compressed seat cushion foam to stress relieve. This estimated time includes taking measurements, pre-test still photos, calibrating the data acquisition system, and charging the servo-sled.

Table 2. Test Matrix

Thickness (in)	Version	Goal G	Cushion Color	Test Number
2	Original	14	Blue	A15005
2	Original	14	Pink	A15007
2	Original	19	Pink	A15001
2	Original	19	Blue	A15003
2	AC	14	Blue	A15006
2	AC	14	Pink	A15008
2	AC	19	Pink	A15002
2	AC	19	Blue	A15004
4	Original	14	Blue	A15018
4	Original	14	Pink	A15019
4	Original	19	Blue	A15014
4	Original	19	Pink	A15016
4	AC	14	Blue	A15017
4	AC	14	Pink	A15020
4	AC	19	Blue	A15013
4	AC	19	Pink	A15015
4	AC	19	Pink	A15021
4	AC	19	Pink	A15022

RESULTS

Initially the FAA Hybrid III was measured on the wooden seat without any cushion to get the nominal 1-G H-point height. The ATD was then seated on each cushion and a 1-G measurement was recorded. Table 3 summarizes the cushion compression for the test articles. Row 1 shows the nominal value for the FAA Hybrid III H-point height on a bare seat with a seat pan at 5°. The remaining rows show the heights for each cushion. The initial cushion compression is the cushion thickness less the difference between the no-cushion H-point height and the H-point height on the cushion. The H-point position was measured by photometrics during the dynamic test. These data were used to determine the maximum vertical (along z-axis) distance the pelvis traveled into the cushion relative to its initial pre-test position.

Table 3. Compression Summary

Thickness	Version	Cushion Color	Goal G	H-Point Height at 1-G (in)	Initial Cushion Compression (in)	H-Point Z max motion (in)
N/A	N/A	No Cushion	N/A	3.86	N/A	N/A
2.0	Original	Pink	14	4.83	1.03	0.9
2.0	AC	Pink	14	4.76	1.10	0.7
2.0	Original	Pink	19	4.82	1.04	0.8
2.0	AC	Pink	19	4.76	1.10	0.8
2.0	Original	Blue	14	5.01	0.85	0.7
2.0	AC	Blue	14	5.20	0.66	0.9
2.0	Original	Blue	19	5.01	0.85	0.8
2.0	AC	Blue	19	4.97	0.89	1.0
4.0	Original	Pink	14	6.13	1.73	1.7
4.0	AC	Pink	14	6.07	1.79	1.8
4.0	Original	Pink	19	6.10	1.76	2.3
4.0	AC	Pink	19	5.84	2.02	1.9
4.0	Original	Blue	14	7.35	0.51	2.3
4.0	AC	Blue	14	7.13	0.73	2.0
4.0	Original	Blue	19	7.19	0.67	2.5
4.0	AC	Blue	19	7.12	0.74	2.4

The lumbar load time-history produced in the tests of the 4-inch thick cushions is provided in Figure 6. As can be seen in Figure 3, the 19 G acceleration onset rate is nearly twice the 14 G rate. Figure 6 shows that lumbar loading rates are clearly related to sled acceleration onset rate with the 19 G tests producing loading rates that are at least twice the rates seen in the 14 G tests. For both loading levels, the AC pink cushions exhibited a slightly higher loading rate than the original pink formulation, while the loading rate for the blue cushions was nearly identical. Loading rate differences are of interest because the rate of spinal loading can affect the type and severity of spinal injuries produced [9].

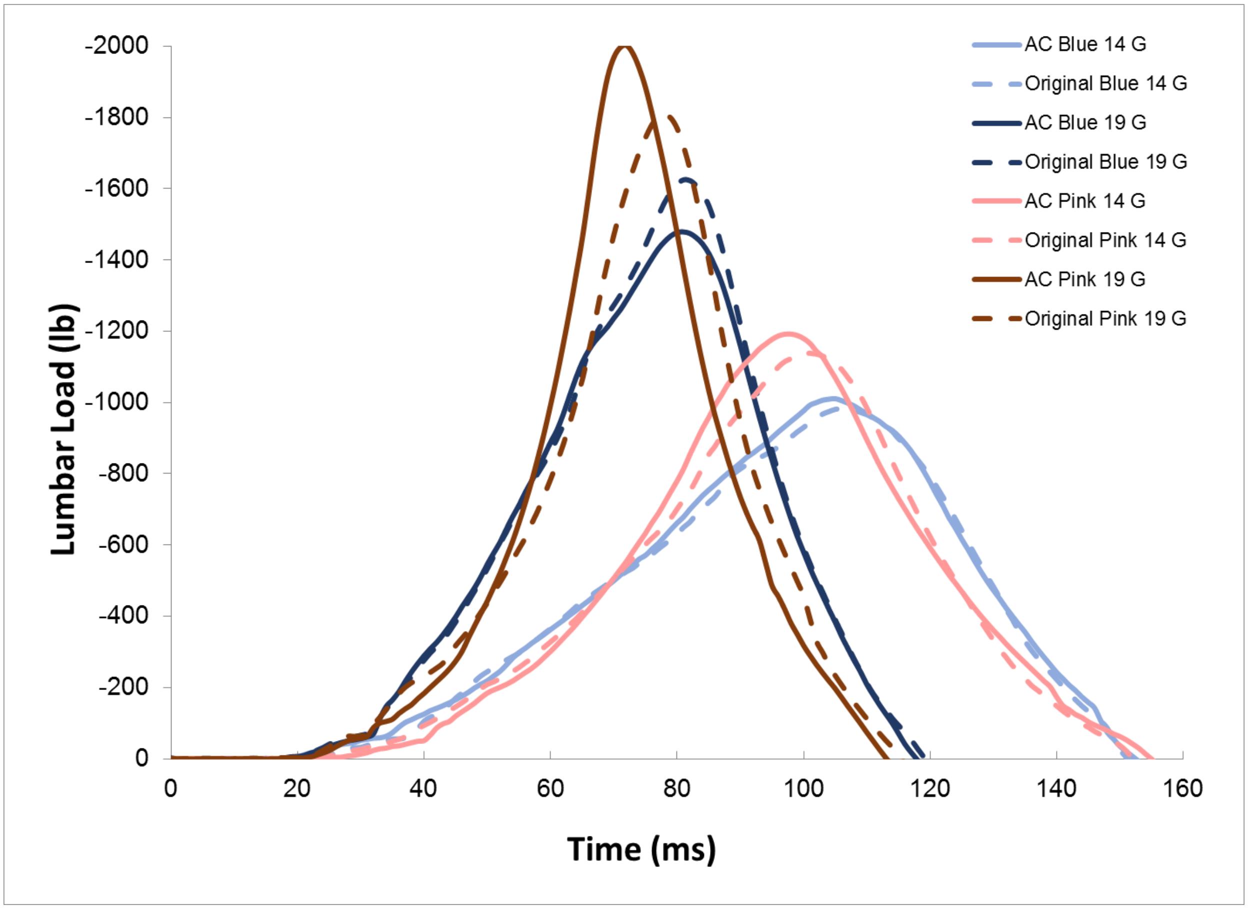

Figure 6. Lumbar Load Time History

To compare the dynamic force/deflection response for each 4-inch thick cushion, the vertical position of the ATD hip point was plotted against the tare corrected seat pan vertical load. (Figures 8 and 10) The motion shown in these plots is a combination of the ATD pelvis and the cushion dynamic compliance. Since the pelvis contribution should be similar for all tests at a given load, the data should be useful for comparison of the foam dynamic response. Note the load magnitude shown does not reflect the initial 1 G preload into the cushion, which is approximately 130 lb.

Blue Confor™

The blue Confor™ original and AC formulation foams were evaluated at two test severities and two thicknesses, for eight tests total (Table 4 and Figure 7). At 14 G, the 2-inch, AC formulation cushion had a 10 lb lower normalized lumbar load than the original formulation. At 19 G, the 2-inch, AC formulation's lumbar load was 95 lb more. At both 14 G and 19 G, the 2-inch AC cushions produced a difference in vertical H-Point Z motion that was 0.2 inch more than the original. At 14 G, the 4-inch, AC formulation cushion lumbar load was14 lb more than the original formulation, and at 19 G, the AC formulation produced 44 lb less lumbar load than the original formulation. At 14 G, the AC cushion had 0.3 inch less vertical pelvis excursion than the original cushion, and at 19 G the AC excursion was 0.1 inch less than the original.

Table 4. Blue Confor™ Summary

Test Parameter	Test Number							
Blue	A15005	A15006	A15003	A15004	A15018	A15017	A15014	A15013
Cushion Thickness (in)	2	2	2	2	4	4	4	4
Version	Original	AC	Original	AC	Original	AC	Original	AC
Goal H-Point Z (in)	5.05	5.09	5.05	5.09	7.40	7.18	7.40	7.18
Achieved H-Point Z (in)	5.01	5.20	5.01	4.97	7.35	7.13	7.19	7.12
Goal Pelvis Angle (°)	-10.1	-10.0	-10.1	-10.0	-9.4	-9.5	-9.4	-9.5
Achieved Pelvis angle (°)	-10.3	-8.5	-10.2	-9.6	-10.5	-10.4	-10.1	-9.9
Impact Velocity (ft/s)	35.3	35.3	33.8	33.5	35.3	35.3	33.7	33.4
Impact Acceleration (G)	14.5	14.4	19.4	19.3	14.4	14.6	20.4	19.1
Normalized Lumbar Load Fz (lb)	970	960	1509	1604	956	970	1514	1470
Seat Pan Fz (lb)	1968	2019	3074	3270	2166	2242	3230	2981
Foot Rest Fz (lb)	706	711	962	989	801	797	1161	1047
H-Point Z max motion (in)	0.7	0.9	0.8	1.0	2.3	2.0	2.5	2.4

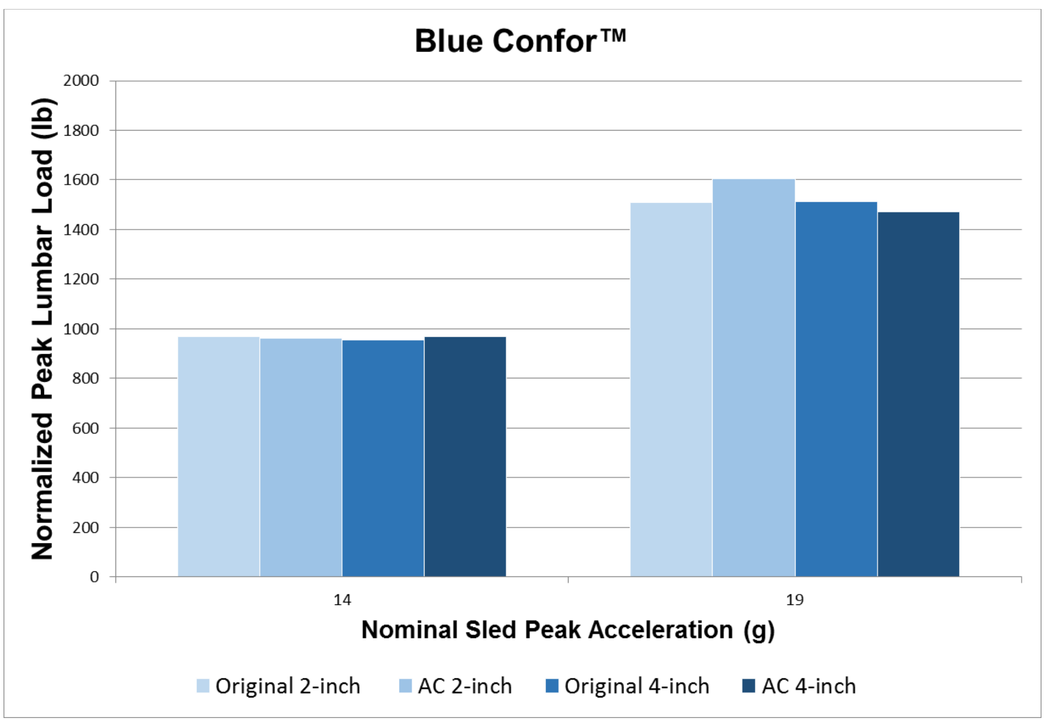

Figure 7. Blue Confor™

Figure 8 shows a comparison of the H-Point vertical position for the 4-inch original and AC blue foam cushions at the 14 G and 19 G peak accelerations. These plots characterize the combined dynamic force/deflection response of the bottom of the ATD pelvis and the cushion. The original and AC foams had very similar response throughout the test at the 19 G loading level. Although the response initially differed for the foams at the 14 G load level, once the pelvis position reached about 6.5 inches, the responses merged and nearly overlaid throughout the rest of the test. The initial difference in the 14 G tests was due to a 0.22 inch higher initial position of the pelvis in the original blue test vs. the AC blue test. This graph also illustrates the effect that loading rate has on both the original and AC formulations of this foam. The F/D response for the 19 G loading level is stiffer than for the 14 G loading level up to 1250 lb, after which the response is similar; the slope of the F/D curves are nearly parallel.

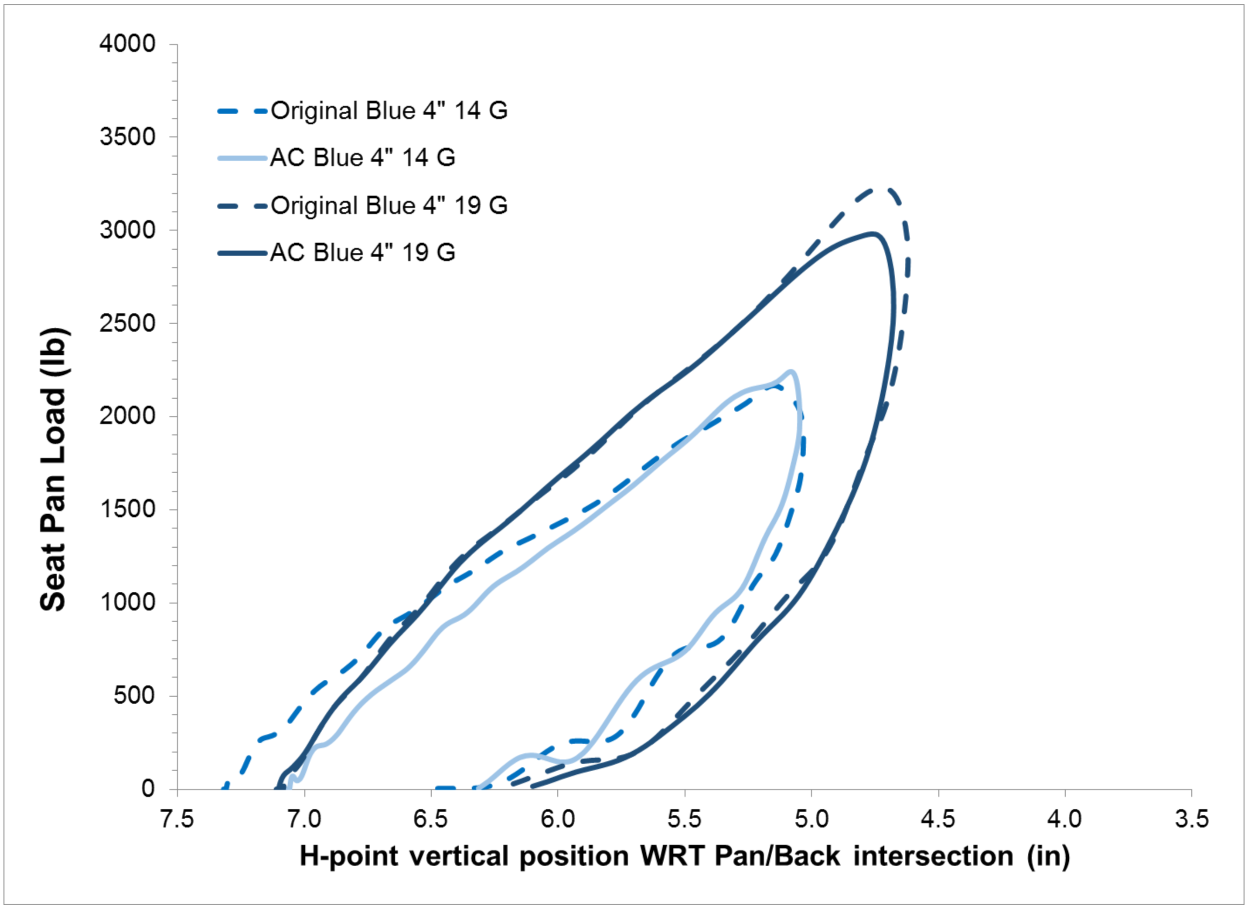

Figure 8. Blue Confor™ H-Point vertical position with respect to Pan/Back intersection for 4” thickness at 14 G and 19 G peak acceleration

Pink Confor™

The pink Confor™ foam original and AC formulations, which are less stiff foam than the blue, were evaluated using the same eight configurations used for the blue tests (Table 5). The 4-inch thick AC formulation cushion was tested a total of three times at 19 G. Figure 9 shows a bar chart summarizing the normalized peak lumbar load produced by the original and AC pink foams at 14 and 19 G respectively. Only the first of the three repeated 19 G tests, number A15015, is shown. At 14 G the 2-inch, AC formulation cushion produced a normalized lumbar load that was 65 lb more than the original cushion test. At 19 G, the 2-inch, AC formulation produced 34 lb less than the original cushion. At 14 G the 2-inch, AC formulation’s vertical pelvis excursion was 0.2 inch less than the original, and at 19 G the excursions were about the same. At 14 G, the 4-inch, AC formulation lumbar load was 53 lb more than the original, at 19 G the AC formulation was 191 lb more. At 14 G, the 4-inch AC formulation’s vertical pelvis excursion was 0.1 inch more than the original, and at 19 G the AC was 0.4 inch less.

Table 5. Pink Confor™

Test Parameter	Test Number									
Pink	A15007	A15008	A15001	A15002	A15019	A15020	A15016	A15015	A15022	A15021
Cushion Thickness (in)	2	2	2	2	4	4	4	4	4	4
Version	Original	AC	Original	AC	Original	AC	Original	AC	AC	AC
Goal H-Point Z (in)	4.88	4.74	4.88	4.74	5.98	5.92	5.98	5.92	5.92	5.92
Achieved H-Point Z (in)	4.82	4.76	4.83	4.66	6.13	6.07	6.10	5.84	5.84	6.00
Goal Pelvis Angle (°)	-12.5	-12.5	-12.5	-12.5	-13.5	-15.7	-13.5	-15.7	-15.7	-15.7
Achieved Pelvis Angle (°)	-11.8	11.5	-11.6	-11.3	-12.1	-14.7	-12.8	-15.2	-14.3	-13.7
Impact Velocity (ft/s)	35.3	35.2	33.3	32.9	35.7	35.4	33.2	33.4	33.4	33.4
Impact Accelera-tion (g)	14.5	14.2	19.4	19.2	14.5	14.5	19.4	19.4	19.4	19.4
Normalized Lum-bar Load Fz (lb)	983	1048	1694	1660	1100	1153	1771	1962	1975	1951
Seat Pan Fz (lb)	2048	2108	3695	2960	2318	2413	3581	3692	3695	3590
Foot Rest Fz (lb)	767	777	1165	1075	846	869	1135	1289	1165	1216
H-Point Z max motion (in)	0.9	0.7	0.8	0.8	1.7	1.8	2.3	1.9	1.8	1.9

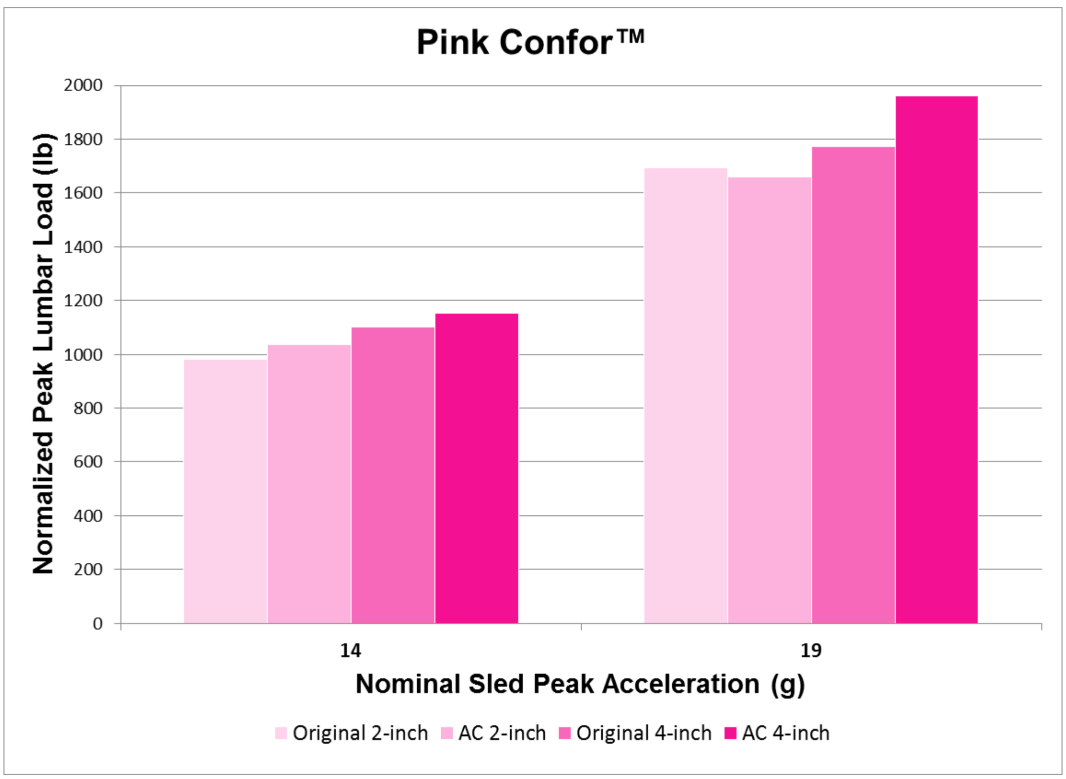

Figure 9. Pink Confor™

Figure 10 shows a comparison of the H-Point vertical position for the 4-inch original and AC pink foams for the 14 G and 19 G peak accelerations. These plots characterize the combined dynamic force/deflection response of the bottom of the ATD pelvis and the cushion. The original and AC foams had very similar response throughout the test at the 14 G loading level. Although the response was initially less stiff for the AC foam at the 19 G load level, after the pelvis position reached 4.3 inches, the stiffness surpassed the original foam response. The initial difference in the 14 G tests was due to a 0.26 inch lower initial position of the pelvis in the AC pink test vs. the original pink test. The rate of loading does not appear to affect the response of the original foam since the F/D response was similar for both the 14 and 19 G tests. The loading rate did appear to increase the rate of stiffness change for the AC foam at 19 G compared to the 14 G test, although that could be in part attributable to the difference in cushion initial compression. Overall, these results indicate that the AC pink Confor™ was both a little stiffer than the original formulation and more rate sensitive.

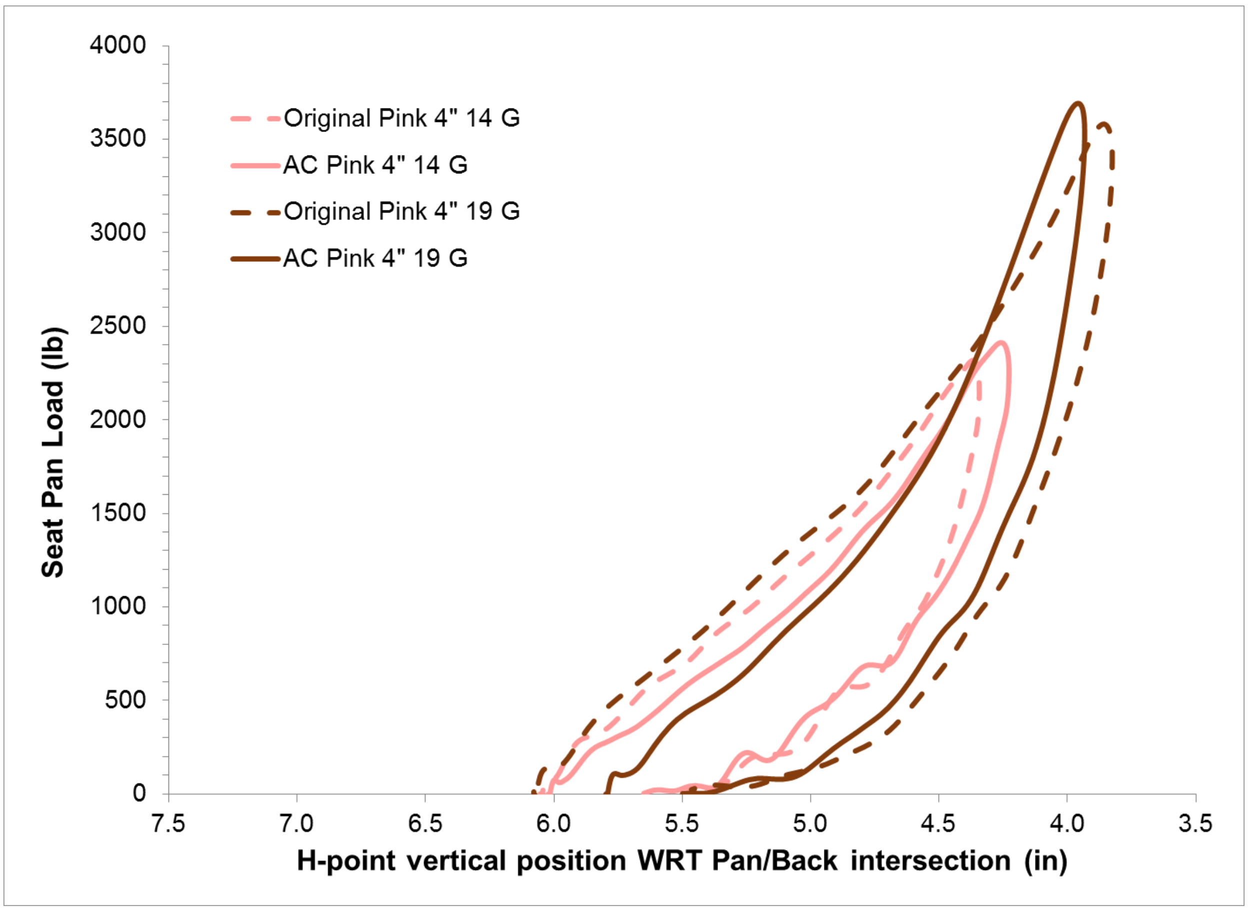

Figure 10. Pink Confor™ Force Deflection curve for 4” thickness at 14 G and 19 G peak acceleration

Test Repeatability

One of the test conditions was run two more times to evaluate test repeatability in this test series. The test condition selected was the AC formulation, 4-inch thick pink Confor™ foam at the 19 G severity. This condition was selected because variability generally increases with lumbar load magnitude [4], and this test condition produced the highest lumbar load of the series. The difference between these 3 repeated tests was less than 25 lb, with a standard deviation of only 12 lb. The force-deflection response was also very similar for these three tests as shown in Figure 11. The third test F/D curve was offset from the others due to a small difference in initial seated height but was otherwise very similar to the other two tests. Coupled with the observation in reference 4, these data suggest that the error on the lumbar load data in this report has an upper bound of ±1.3%, based on 2 standard deviations from the mean. This error accounts for repeated cushion tests with the same test article and a single ATD and may only be applicable to this test series. While the error bound includes the variability in the test methodology with tightly controlled seating parameters, it does not include the cushion variability, ATD-to-ATD variability, or lab reproducibility.

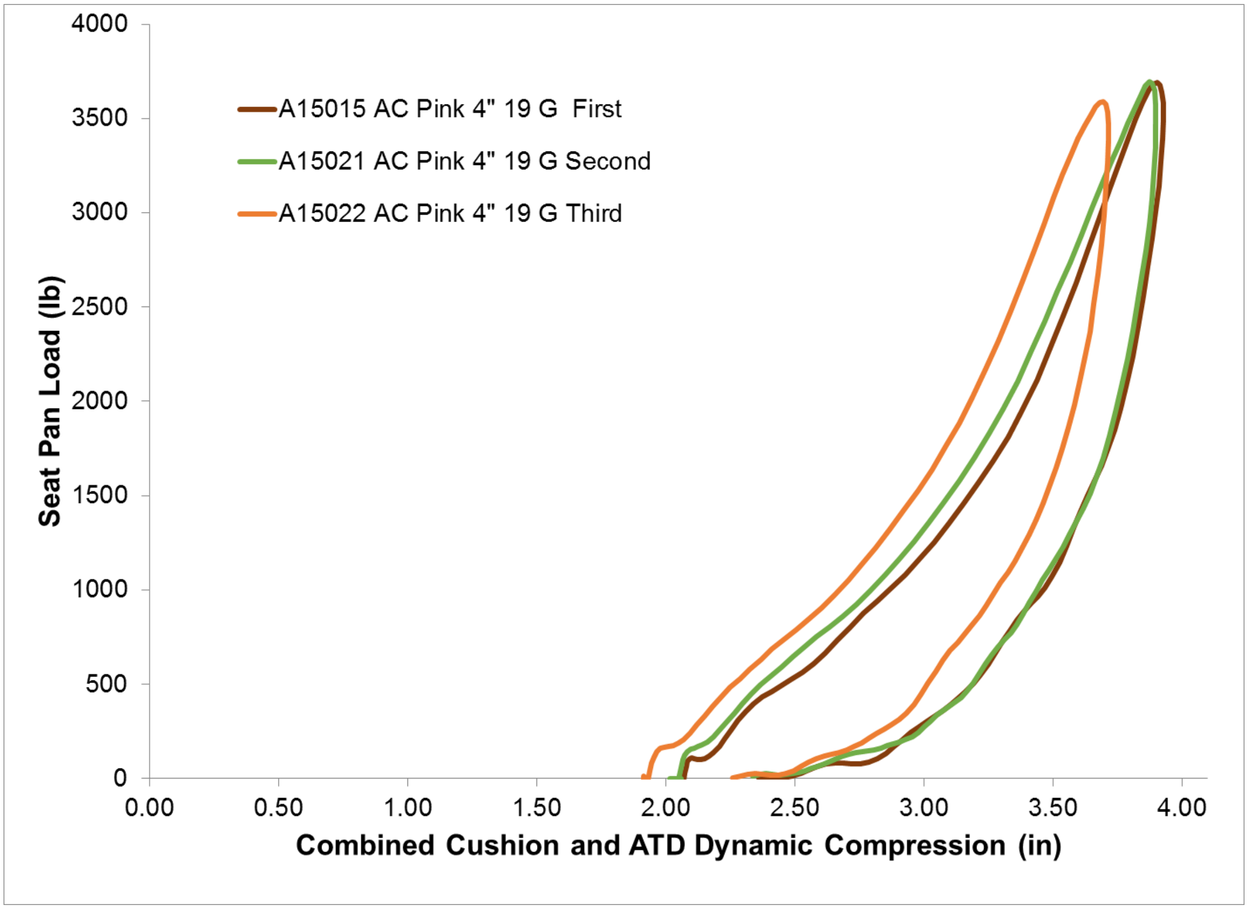

Figure 11. Pink Confor™ Force Deflection curve for 4” thickness at 19 G peak acceleration - 3 repeated tests

DISCUSSION

The results showed that for each material formulation, cushion thickness, and impact level, the blue type foam produced lower lumbar loads than the pink type. However, the results yielded no clear trend for material formulation or thickness, i.e. the AC foams did not always produce higher lumbar load than original, and thicker cushions did not always produce higher lumbar loads. Specifically, the blue AC formulation produced lumbar loads between 2.9% less and 6.4% greater than the original version. The pink AC formulation produced lumbar loads between 2.0% less and 10.8% greater than the original version.

All of the 14 G tests produced lumbar loads that were significantly less than the 1500 lb limit and had minimal variation in load between the original and AC formulation foams. All of the 19 G tests produced lumbar loads that were near to, or significantly exceeded the 1500 lb regulatory injury limit. This means that the loads applied in that test condition are greater than what would occur during successful qualification tests of a real seat. Since lumbar load variability appears to be related to peak load, it would be expected that the variation between the original and AC cushions would be less than what was measured during this project if the 19 G test condition was reduced to ensure all produced loads were below 1500 lb. This should be considered when evaluating reported lumbar load differences.

These tests were conducted with a single ATD, and while good repeatability was achieved, the lack of ATD dynamic vertical calibration standards means that repeating these tests with a different ATD could result in different results. The Hybrid III pelvis used for this series must meet a specific compressed height requirement, ±0.07 inch, versus a ±0.2 inch requirement for the Hybrid II, which should control vertical performance variation between test dummies, somewhat. However, development and implementation of a vertical dynamic calibration method for ATDs used in aviation tests would be the best way to ensure an acceptable level of reproducibility. For basic material comparisons, dynamic tests with a high-rate load frame would have the advantage of eliminating all ATD variability.

Another factor to consider when comparing the reported lumbar loads is that this project did not attempt to quantify the effect that normal production variability in foam characteristics has on dynamic performance. While the test articles were cut from single layers of foam to reduce variation, how those articles compare to other foam buns or even other layers within the same bun is unknown.

In addition to lumbar load, when changing the design of a seat cushion used on a dynamically qualified seat, one concern is whether the AC cushion will raise the initial position of the occupant significantly, affecting the seat overturning moment during horizontal loading or HIC compliance. For the tested configuration (a flat rigid seat pan), there was very little difference in initial 1 G seated height between the original and AC formulations for both types and thicknesses examined. The difference ranged from 0.22 inch lower ATD H-point height for the 4-inch thick blue foam to 0.04 higher for the 2-inch thick blue foam. Policy memo ANM-115-05-005 allows for a 0.5 inch difference in seated height when replacing monolithic cushions [10].

LIMITATIONS

Due to limited availability of test articles, each formulation was only tested once at each peak G level. The repeated case with the pink Confor™ only utilized one sample, which was rotated and flipped to expose different areas. The uncertainty due to this limited sample is mitigated somewhat by the excellent measured repeatability for the case expected to produce the highest variability. The scope of the project and the availability of test articles prevented an evaluation of that effect that production variability could have on dynamic material characteristics and lumbar load.

This scope of this project did not include investigating differences in flammability between the original and AC foams, which may also have been affected by the formulation change.

CONCLUSION

Dynamic tests of the original and AC Confor™ formulations produced similar lumbar loads for two types, CF-42 (pink) and CF-45 (blue) and two thicknesses at the 14 G acceleration levels. At the 19 G level, lumbar loads for the original and AC foams diverged some, but the largest difference in peak lumbar load produced by the AC version was 11% greater for pink Confor™ and 6% greater for blue Confor™. If some level of production variability is assumed, then these values suggest that there may not be a significant difference between the impact performance of the original and AC formulation for aircraft bottom seat cushion applications. Since the three formulations (Standard, M, and AC) look similar, and it is possible that not all distributors have revised their part numbers to reflect the formulation change, end users should ensure that the correct formulation is obtained for aviation seating systems, and that the flammability performance is suitable for their specific application.

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