DYNAMIC TESTING OF HIGHLY DAMPED SEATING FOAM

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Presented at the XXIV OSTIV Congress, Omarama, New Zealand (1995)

ABSTRACT

A dynamic test was carried out on domestic seating foam and on two types of highly damped seating foams. The test was carried out at 17 G and 9.4 m/s, using three Hybrid III mannequins - 5th percentile female, 50th percentile male, and 95th percentile male. Using 'Dynafoam' (called 'Sunmate' in the U.S.A.), there was a significant logarithmic relationship between foam thickness and reduction in lumbar spinal load. The foam absorbed significant energy even after four years intensive use in glider seating. Cold foam absorbed impact energy, but this portion of the test has to be considered unreliable. Another foam, 'Plastazote', was tested briefly and also showed reduction in spinal load. However, it showed continued deformation for some time after the test impact. The domestic seating foam showed a slight reduction or no change in spinal load - previous tests have always shown an increase in spinal load. The lumbar spinal load in the 95th percentile male was less than the load in the 50th percentile male mannequin; this finding requires a logical explanation.

METHOD

The test was carried out using the facilities of the test track at the Defense Research Agency Center for Human Sciences, Farnborough, England. Three Hybrid III Anthropomorphic Test Devices (henceforth called 'mannequins') were used - 5th percentile female, 50th percentile male, and 95th percentile male. They were instrumented as follow:

Vehicle G.

Pelvis Gx and Gz.

Thorax Gx and Gz.

Lumbar Fx, Fz and My. (The lumbar Fz reading was the significant value in this test).

Outputs from transducers were collected through a series of flying leads to Measurements Group 2120A signal conditioning amplifiers, and thence to a Metrabyte DAS16 data acquisition card fitted to an IBM compatible PC. Signals were processed using ASYST SCIENTIFIC software, which was also used as the data acquisition software.

Lumbar and pelvic traces were filtered to SAE Channel class 1000.

Thorax traces were filtered to SAE Channel class 180.

Vehicle traces were filtered to SAE Channel class 60.

All traces were processed to I.A.W. SAE J211 draft, dated 10th August 1994.

The technical details of the transducers used in this

	HYBRID III 5th % FEMALE (Fig.1)	HYBRID III 50th % MALE (Fig.2)	HYBRID III 95th % MALE (Fig.3)
LUMBAR My	DENTON MODEL 2152 SER No 091	DENTON MODEL 1842 SER No 0123	DENTON MODEL 1842 SER No 0123
LUMBAR Fx	DENTON MODEL 2152 SER No 091	DENTON MODEL 1842 SER No 0123	DENTON MODEL 1842 SER No 0123
LUMBAR Fz	DENTON MODEL 2152 SER No 091	DENTON MODEL 1842 SER No 0123	DENTON MODEL 1842 SER No 0123
THORAX Gx	ENDEVCO MODEL 7231-750 SER No A23G	ENDEVCO MODEL 7231-750 SER No A23G	ENDEVCO MODEL 7231-750 SER No A23G
THORAX Gz	ENDEVCO MODEL 7231-750 SER No A76K	ENDEVCO MODEL 7231-750 SER No A76K	ENDEVCO MODEL 7231-750 SER No A76K
PELVIS Gx	ENDEVCO MODEL 7231-750 SER No A97H	ENDEVCO MODEL 7231-750 SER No A97H	ENDEVCO MODEL 7231-750 SER No A97H
PELVIS Gz	ENDEVCO MODEL 7231-750 SER No A51J	ENDEVCO MODEL 7231-750 SER No A51J	ENDEVCO MODEL 7231-750 SER No A51J
VEHICLE G	ENDEVCO MODEL 7231-750 SER No A98F	ENDEVCO MODEL 7231-750 SER No A98F	ENDEVCO MODEL 7231-750 SER No A98F

TABLE 1. Technical details of transducers.

test are given in Table 1.

The position of the transducers is shown in Diagram 1. It will be seen that the load cells in the lumbar spine of the male mannequins are angled at 22° to the longitudinal axis of the mannequin. The reason for this is as follows. The mannequins are designed for use in motor vehicle testing. Short drivers sit upright, so the 5th percentile female mannequin is designed with the load cell at right angles to the longitudinal axis. Taller drivers sit flexed forward, so the load cells are angled at 22° to the longitudinal axis of the male mannequins. Mathematically, it does not matter whether the load cells are angled forward or backward, as all the mannequins are sitting upright for the actual test. The readings from the load cells give the actual load that would be experienced by a pilot, have been given in pounds force (lb. ft..) and in kiloNewtons (kN) in Table 2.

Criticism has been expressed concerning the use of load cells in the lumbar spine of the Hybrid III mannequin (Reference 1). The spine does not have individual vertebrae, and insertion of a load cell into the lumbar region stiffens an area representing several vertebrae, into a virtually rigid unit.

Ballast was bolted to the test vehicle when the 5th percentile female and 50th percentile male mannequins were tested. The total weight of vehicle and mannequin then approximated that of the vehicle and the 95th percentile mannequin. This enabled the impact velocity to be kept constant within narrow limits (see Table 2).

High speed video equipment was used to record the impact.

Difficulty was experienced in achieving the nominal G value. The achieved G was low in the following test runs; allowance should be made for this in assessing the results.

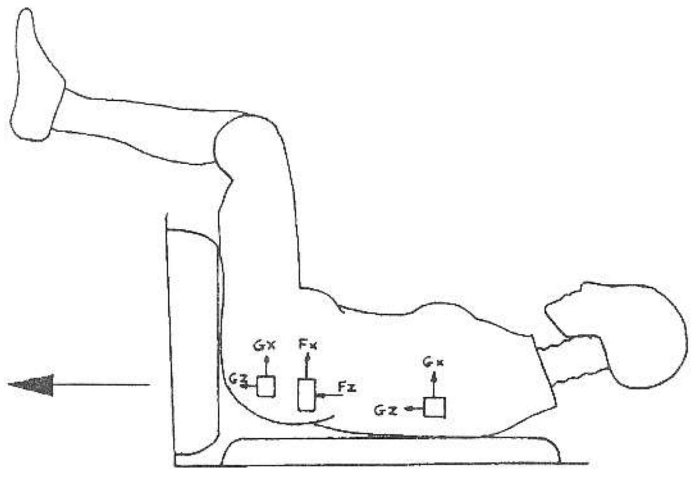
TS 4170-5A-17 (5th% - no cushion). 16.6 G. (Nominal value - 17 G). TS 4186-50D-17 (50th% - 1" Dynafoam). 16.5 G.

TS 4187-50E-17 (50th% - 2" Dynafoam). 16.1 G.

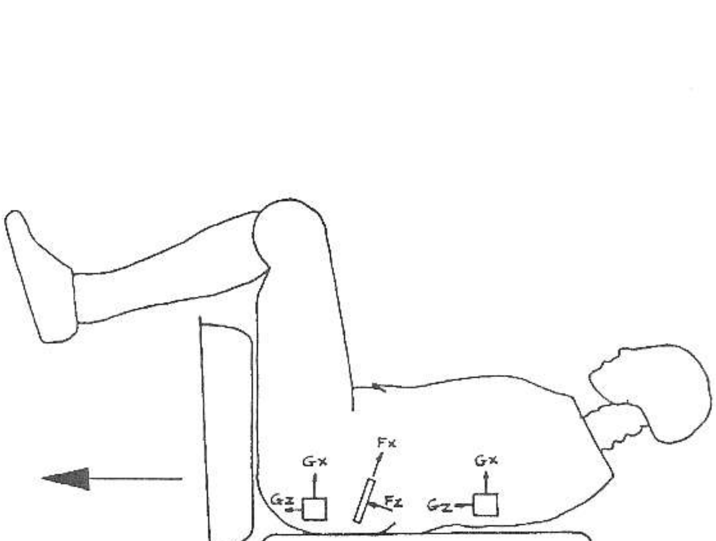
The temperature in the test track building varied between 16.5 and 23.9° C during the course of the test as the ambient temperature varied. It is not considered that this will have had a significant effect on the test results.

The seat used was a stiff R.A.F. aircrew equipment Personal Survival Pack cover, made of glass reinforced plastic. m is was firmly bolted to a solid metal frame. During the course of the test run with the 50th percentile mannequin, the rear of the seat broke (This seat had been used in a number of previous tests). Following repair, repeat tests showed no significant alteration in results.

The mannequin was placed on the seat lying on its back. At this stage, the cushion was placed between the mannequin and the seat. The five-point harness was secured. The mannequin was moved firmly onto the seat, and the harness tightened. The seat was rotated upright through 90°, and the harness again tightened. This enabled the seat cushion to be loaded to 1 G. The seat was then rotated back through 90° , and the



5th Percentile Female Manikin



50th and 95th Percentile Male Manikins

DIAGRAM 1. Position of transducers in manikin.

DYNAMIC TEST ON GLIDER SEATING FOAM

RUN NUMBER	FOAM	VELOCITY m/s	ACHIEVED G	LUMBAR Fz lb.f.	LUMBAR Fz kN
5th PERCENTILE FEMALE MANIKIN					
TS 4170-5A-17	No cushion	9.4	16.6	1249	5.558
4171-5B-17	4" soft foam	9.4	17.8	981	4.365
4172-5B-17	4" soft foam	9.4	17.5	1143	5.085
4173-5C-17	1/2"Dynafoam	9.4	17.0	1083	4.819
4174-5C-17	1/2"Dynafoam	9.4	17.0	1055	4.695
4175-5D-17	1" Dynafoam	9.4	17.4	1038	4.619
4176-5E-17	2" Dynafoam	9.4	17.3	823	3.662
4177-5F-17	4" Dynafoam	9.4	17.2	767	3.413
4178-5G-17	1" Dynafoam (used)	9.4	17.1	938	4.174
4179-5H-17	2" Dynafoam (cold, 1°C)	9.4	17.1	867	3.858
4180-5J-17	2"Plastazote	9.4	17.0	841	3.742
50th PERCENTILE MALE MANIKIN					
TS 4181-50A-17	No cushion	9.4	17.6	2035	9.056
4182-50A-17	No cushion	9.4	16.9	2056	9.149
4185-50A-17	No cushion	9.3	16.3	1972	8.775
4183-50B-17	4" soft foam	9.4	17.6	1858	8.268
4184-50C-17	1/2"Dynafoam	9.4	17.3	1837	8.175
4186-50D-17	1" Dynafoam	9.3	16.5	1690	7.520
4187-50E-17	2" Dynafoam	9.3	16.1	1402	6.239
4188-50F-17	4" Dynafoam	9.3	17.5	1183	5.264
4189-50G-17	1" Dynafoam (used)	9.4	16.9	1701	7.569
4190-50H-17	2" Dynafoam (cold 1°C)	9.4	17.5	1679	7.472
4191-50J-17	2"Plastazote	9.4	17.4	1410	6.274
95th PERCENTILE MALE MANIKIN					
TS 4199-95A-17	No cushion	9.5	18.0	1716	7.636
4211-95A-17	No cushion	9.5	17.6	1519	6.760
4201-95B-17	4" soft foam	9.5	18.6	1630	7.253
4202-95B-17	4" soft foam	9.5	18.5	1734	7.716
4212-95B-17	4" soft foam	9.5	18.2.	1658	7.378
4213-95B-17	4" soft foam	9.5	18.5	1735	7.721
4203-95C-17	1/2"Dynafoam	9.5	17.4	1491	6.635
4204-95D-17	1" Dynafoam	9.5	17.3.	1345	5.985
4205-95E-17	2" Dynafoam	9.5	17.6	1241	5.527
4206-95F-17	4" Dynafoam	9.5	18.0	1056	4.699
4207-95G-17	1" Dynafoam (used)	9.5	17.4	1418	6.310
4208-95H-17	2" Dynafoam (cold 0.4°C)	9.5	17.3	1396	6.212
4209-95J-17	2"Plastazote	9.5	17.4	1308	5.821
4210-95J-17	2"Plastazote	9.5	17.9	1496	6.657

TABLE 2

test carried out. To reduce the effect of friction between the mannequin and the seat back, the mannequin wore a cotton vest, and a sheet of polyethylene was secured to the seat back. Difficulty was experienced in securing the seat harness when the thick foam (10 cm thick) was used.

TEST PARAMETERS

The axis of the spine of the mannequin was aligned with the direction of movement of the test vehicle. The seat pan was at right angles to this axis. It was considered that to have the mannequin spine angled backwards, as in modern glider seating, would produce an unnecessary complication in assessing the effect of the cushion material.

The deceleration force of the crash impact used the values recommended in the US Army Air Mobility Research and Development Laboratory "Crash Survival Design Guide"(Reference 2 and 3). The values are a peak G of 17 Gz and a velocity change of 9.4 m/s (21 mph). 76% of all potentially survivable crashes occur at deceleration and velocity levels below these values.

RESULTS

These are given in Table 2 .

There was a significant reduction in lumbar spinal load when Dynafoam cushions were used. This held good for all three mannequins - The load reduced further as the thickness of cushion increased. This reduction in load was logarithmic in character, the effect reducing as cushion thickness increased. The graphs in Diagram 2 clearly show this effect.

A Dynafoam seat cushion that had been in use for four years in a K-13 training glider of the Lasham Gliding Society showed significant reduction in lumbar spinal load. This reduction was only slightly less than for new unused foam. A Lasham K-13 glider undergoes approximately 3000 landings a year. The seat cushion tested had therefore been used in 12000 landings during the four years.

An attempt was made to assess the effect of temperature on the foam. It is well known that the foam becomes harder in the cold, and softer in the warm. The foam was cooled to between 0°C and 1°C for several hours. It was then placed in the test rig, and a test run carried out. However, setting up the rig for a test run took approximately ten minutes, during which the foam would have warmed considerably. The cold foam showed considerable reduction in lumbar spinal load. The effect of warming on the foam was not tested. The results obtained have to be treated with caution. Another experimental group (Reference 4) had similar problems and were unable to reach a definite conclusion on the effect of temperature,

A limited test was carried out on another type of highly damped seating foam, "Plastazote This showed a reduction in lumbar spinal load equivalent to that of "Dynafoam." However, the "Plastazote" showed only slow recovery after impact.

The domestic seating foam gave an unexpected result. While the 5th percentile female and the 50th percentile male showed some reduction in lumbar spinal

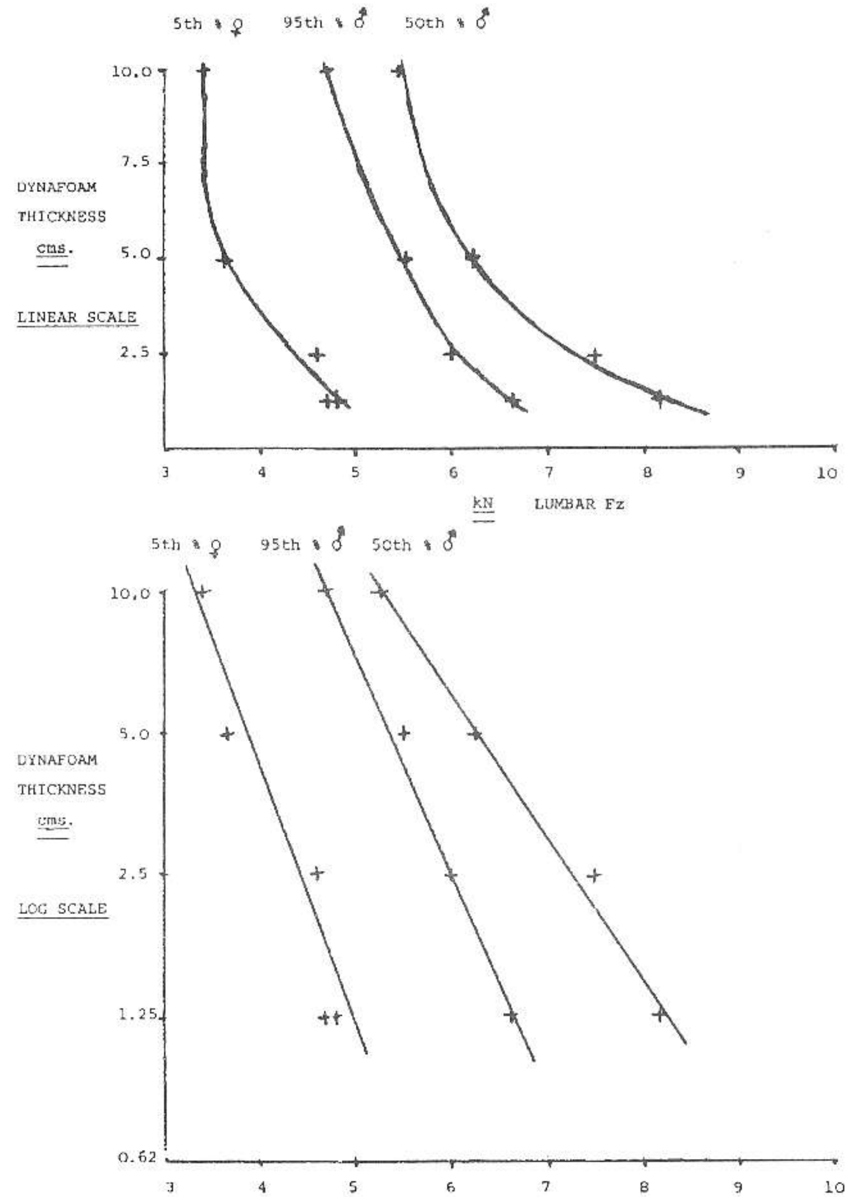


DIAGRAM 2. Relationship of "Dynafoam" thickness to lumbar spinal load.

load, the 95th percentile male mannequin, during four test runs, showed either a slight reduction or a slight increase in lumbar spinal load. Previous tests have shown that soft foam increases the spinal load (Reference 3, 5, 6). The foam was high quality seating foam purchased from a shop providing foam for upholstery. Modern upholstery tends to be made firmer than in the past, so the foam used will be stiffer. This is probably the reason for this result. However, the reduction in spinal load is far better when "Dynafoam" is used, instead of domestic seating foam.

The loads on the spine of the 95th male mannequin were generally lower than those in the 50th percentile male dummy. This result is surprising. The explanation may be that the 95th % mannequin has a larger bearing area on the seat cushion, so more of the foam is available to reduce the spinal load. Also, there will be increased friction between the dummy and the seat back in the case of the 95th percentile mannequin.

CONCLUSION

A highly damped seating foam, "Dynafoam," significantly reduced lumbar spinal loads in the Z axis, when submitted to an impact of 17 G and 9.4 m/s velocity change. This was shown with Hybrid III mannequins - 5th percentile female, 50th percentile male, and 95th percentile male. The foam retained its property of reducing spinal load, after four years intensive use in a training glider. A preliminary test on cold foam showed it retained its load reducing property - this result should be treated with caution. It is suggested that a further test on the effect of cold and heat on the foam should be carried out. If this foam were to be used in helicopters, tests should be carried out to find out the effect of the foam on vibration. Rapid decompression from 5000 ft to 25000 ft did not adversely affect the structure of "Dynafoam" (See the addendum).

ACKNOWLEDGMENTS

We are grateful to Dr. Kevin Browne for his assistance with the mathematical analysis of the test results.

We thank RD Aviation Limited, Kidlington, Oxford, UK, for their assistance with the supply of the "Dynafoam" used in this test.

ADDENDUM

Samples of "Dynafoam" were placed in the Altitude Chamber of the Defense Research Agency, Center for Human Sciences, Farnborough. A rapid decompression was carried out in three seconds, from 5000 ft to 25000 ft. There was no macroscopic change in the structure of the foam. We are grateful to Sqn. Ldr. D. Gradwell (Head of Altitude and Life Support), and to Mr. P. Harmer (Higher Scientific Officer), for their help with this test.

REFERENCES

(1) Brownson P., DM Thesis, "The Brace Position for Passenger Aircraft, A Biomechanical Evaluation," University of Nottingham, 1993.

(2) US Army Air Mobility Research and Development Laboratory, "Crash Survival Design Guide."

(3) Air Standardization Coordinating Committee, Advisory Publication 61/90, "Test Methodology for the use of Slow Recovery Foam in Seat Cushions," June, 1993.

(4) Hooper, S. J., Ellis, D., "Preliminary Data Release - Foam Sandwich Seat Cushion Study," May, 1993, (National Institute for Aviation Research, The Wichita State University).

(5) Hearon, B. F., Brinkley, J. W., "Effect of Seat Cushions on Human Response to +Gz Impact," J. Av. Sp. Envir. Med., February, 1986.

(6) Segal, A. M., "Pilot Safety and Spinal Injury," *Technical Soaring*, 1988, Vol XII, No.4.