Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
05 JUL 2014	**Journal Article**	**07-06-2014 to 15-00-2014**

4. TITLE AND SUBTITLE
BLAST MITIGATION SEAT ANALYSIS - DROP TOWER DATA REVIEW

5a. CONTRACT NUMBER
SP0700-03-D-1380

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Booz Allen Hamilton,101 W Big Beaver Rd,Ste 505,Troy,Mi,48084

8. PERFORMING ORGANIZATION REPORT NUMBER
; #25300

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000

10. SPONSOR/MONITOR'S ACRONYM(S)
TARDEC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
#25300

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Blast energy-attenuation (EA) seats, although not new to the market, have not been fully characterized with respect to energy attenuation capability and the resulting effects on occupant protection. The U.S. Army ? Tank Automotive Research, Development and Engineering Center (TARDEC) Ground Systems Survivability (GSS) Interiors Seat Team tested and evaluated EA seats over a one-year period using a drop tower test method. Data from three different anthropomorphic test devices (ATDs, or crash test dummies) was recorded on tests in twelve different seat styles that were dropped at two different heights on the drop tower. The data was checked for quality and anomalies, and a method was developed to display all of the data in an easily referenced and understood format. This data was compared to the Army Research Lab / Survivability / Lethality / Analysis Directorate (ARL/SLAD) crew injury criteria for accelerative events and the enhanced injury assessment reference values (e-IARVs) for the 5th percentile female, 50th percentile male, and 95th percentile male determined from existing biomedical literature by the Occupant Centric Platform (OCP) Technology Enabled Capability Demonstration (TECD) program?s Enhanced Injury Assessment Reference Value Working Group as a pass/fail threshold.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Public Release**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Proceedings of WSU 75th Anniversary Symposium
Injury Biomechanics, Prevention, Diagnosis & Treatment
August 14-16, 2014, Detroit, MI, USA

BLAST MITIGATION SEAT ANALYSIS – DROP TOWER DATA REVIEW

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INTRODUCTION

Blast energy-attenuation (EA) seats, although not new to the market, have not been fully characterized with respect to energy attenuation capability and the resulting effects on occupant protection. The U.S. Army – Tank Automotive Research, Development and Engineering Center (TARDEC) Ground Systems Survivability (GSS) Interiors Seat Team tested and evaluated EA seats over a one-year period using a drop tower test method. Data from three different anthropomorphic test devices (ATDs, or crash test dummies) was recorded on tests in twelve different seat styles that were dropped at two different heights on the drop tower. The data was checked for quality and anomalies, and a method was developed to display all of the data in an easily referenced and understood format. This data was compared to the Army Research Lab / Survivability / Lethality / Analysis Directorate (ARL/SLAD)[1] crew injury criteria for accelerative events and the enhanced injury assessment reference values (e-IARVs) for the 5th percentile female, 50th percentile male, and 95th percentile male determined from existing biomedical literature by the Occupant Centric Platform (OCP) Technology Enabled Capability Demonstration (TECD) program's Enhanced Injury Assessment Reference Value Working Group[2] as a pass/fail threshold.

An evaluation of the data allowed the assessment of commercially available and prototype seats to understand the performance of the seats with varying occupant weights and to evaluate the test methodology and occupant injury assessment performance criteria. The results from this data review afforded a better understanding of how seat design affects performance with varying occupant size, including weight and stature. The analysis also provided the TARDEC Seat Team with an overview of general trends and lessons learned.

METHODS

In efforts to gain an understanding of the current blast EA seats on the market and in development, twelve seat models were evaluated on the drop tower located at the TARDEC Occupant Protection Laboratory (OP Lab). Testing blast mitigation seats on a drop tower has been established as a preliminary evaluation of seat assets without introducing the variability or cost associated with a full-scale blast test. A matrix was developed to assess the seats with a simulated blast input with test variables including two severities (200 g or 350 g peak acceleration pulse), three ATDs (Hybrid III 5th percentile female, 50th percentile male, or 95th percentile male), and with or without personal protective equipment (PPE). The seats were tested in their recommended use range. Several of the seats were designed specifically for the lower input velocities. Efforts were made in the matrix development to maximize information gained with a limited number of seat assets.

Each test included an instrumented and ballasted ATD to measure forces, moments, and accelerations imparted to the occupant. The fleet of ATDs all contained the same instrumentation, which included accelerometers in the head, thorax, and pelvis as listed in Table 1. Load cells to measure forces and moments were located in the upper neck, lumbar spine, femur, upper tibia, and lower tibia. The data recorded off of each transducer was compared to the ARL/SLAD crew injury criteria for accelerative events for the 50th percentile male. The OCP TECD e-IARVs Working Group determined criteria for the 5th percentile female, 50th percentile male, and 95th percentile male from existing biomedical literature.

Table 1. ATD instrumentation channel list.

Location	Channels
Head	Ax, Ay, Az
Upper Neck	Fx, Fy, Fz, Mx, My, Mz
Thorax	Ax, Ay, Az, Dx (displacement)
Lumbar Spine	Fx, Fy, Fz, Mx, My, Mz
Pelvis	Ax, Ay, Az
Femur	Fx, Fy, Fz, Mx, My, Mz (per leg)
Upper and Lower Tibia	Fx, Fy, Fz, Mx, My, Mz (per leg)

RESULTS

The primary focus of the testing was to evaluate the test methodology developed for EA seat analysis via drop tower, namely, the ability of commercially available or prototype seats to produce occupant injury values below the internal OCP thresholds for all body segments for all size occupants. Each ATD channel was reviewed to determine if the maximum or minimum value exceeded the associated IARV limit.

An example of the data analysis for normalized lumbar compression peak values of all 113 tests is shown in Figure 1. A review of the data showed compliance with the OCP IARV limits for some of the seats in the tested configurations, leading to the conclusion that the target loads and accelerations set by OCP were attainable and appropriate.

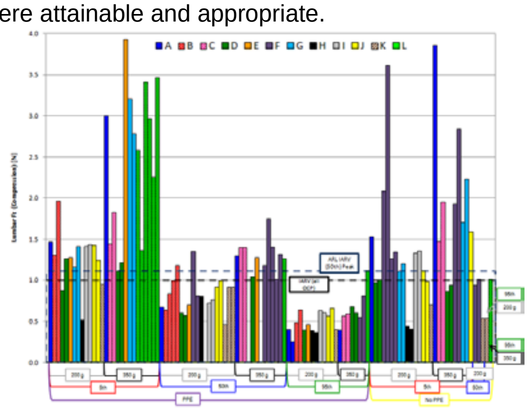

Figure 1. Normalized lumbar Fz compression data compared to OCP IARV limit (black dashed line) and ARL/SLAD peak limit for 50th percentile male (blue dashed line).

Some of the recorded data from the platform was questionable due to various issues with the accelerometers over the full series, including accelerometer mounting problems due to rough or imprecise mounting surfaces and cable tie down issues resulting in damaged or severed cables or cable "whip".

Throughout the test series and accompanying data analysis, several lessons were learned. Although all ATD data channels were reviewed for IARV exceedances, an analysis of the ATD trends allowed for the formation of general observations of "go/no-go" channels to review if time is limited. Lumbar compression (-Fz) seems to be the go/no-go injury criteria when evaluating the seat as a survival system.

A review of lower extremity injury values led to the conclusion that some type of flooring system should be included to mitigate lower leg injuries during a blast event, as confirmed by comparing tibia IARVs between seats that featured foot rests or blast mats relative to those without.

Seat manufacturers currently design their systems for optimization during a blast event with an occupant representative of a 50th percentile male, and many seats were tuned for approximately a 200 g peak acceleration event. Consequently, the majority of the seats passed the lumbar compression load for the 50th percentile male at this test condition. A review of the lumbar compression data for the 95th percentile male demonstrates that the additional weight of the occupant and higher IARV thresholds leads to passing numbers for almost all seat models. As expected, the seats were not designed for the lightest occupant, leading to lumbar compression limits over the threshold of the 5th percentile female for 83% of the seats tested.

The purpose of testing with and without PPE was to determine if the additional weight, in the case of the 95th percentile male, would cause a seat to "bottom out", or if the lack of weight, as in the unencumbered 5th percentile female, was too light to cause the seat to stroke as designed. However, due to the limited data sets, it was difficult to complete comparative analyses between ATDs with and without PPE.

CONCLUSIONS

The drop tower testing and evaluation performed on commercial and developmental seats provided an objective assessment of the seats' performance with respect to the injury criteria. The test methodology and OCP IARV assessment criteria were evaluated and deemed acceptable for future use. Data analysis was performed for a quality check of the data and was used to determine general trends in ATD performance.

Complications with test setups lead to a list of caveats for this data analysis, including the loss of some of the platform accelerometer data.

This evaluation was a preliminary effort to characterize EA seats via a drop tower, understanding that a drop tower test does not perfectly match the kinematics experienced during an actual blast event. This and future drop tower data should be compared to live fire data to identify and quantify similarities and differences in ATD and seat response.

ACKNOWLEDGMENTS

The authors would like to acknowledge the staff at the TARDEC OP Lab for their support on this test series.

REFERENCES:

1. Spink, Robert J. Injury Criteria for the Analysis of Soldier Survivability in Accelerative Events (U). Army Research Laboratory. Technical Paper ARL-TR-6121. September 2012.
2. OCP TECD Enhanced IARV Report, DRAFT, 11JUN13 LM v3, DIST D.
3. TARDEC Occupant Protection Seat Development Final Summary Technical Report. Concurrent Technologies Corporation. 25 April 2013.
4. Felczak, Chris. Detroit Arsenal Standing Operating Procedures for GSS Sub-System Drop Tower. SOP No. TA-0000-P-045. June 2013.