METHODOLOGY FOR ESTABLISHING THE MINE/IED RESISTANCE CAPACITY OF VEHICLE SEATS FOR CREW PROTECTION

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ABSTRACT

Many Army ground vehicles possess structural characteristics that aim to improve the crew survivability when engaged by mine or Improvised Explosive Device (IED). Increased ground clearance, a V-shaped underbody, or high curb weight cooperate to reduce acceleration effects to the crew. The seat, as a critical component of the overall mine blast protection solution, is often overlooked, as evident by the significant number of non-blast-resistant seats featured in army vehicles. Ten unique MRAP-1 candidate seat systems were obtained to evaluate their effectiveness at limiting vertical and lateral acceleration effects to the crew. Using vertical and horizontal shock machines and an instrumented THOR 50th percentile ATD, each seat was subjected to incremental vertical shock tests.

The range of vertical input sustained by all seats was from 5.8 – 8.3 m/s for the seats assessed. Lateral tests conducted at two input levels indicate significant occupant-seat decoupling. Relative displacement of the head's center of gravity from the seat varied from 10-30 inches.

1. INTRODUCTION

Underbody blast threats pose a high risk to a vehicle and it's crew. While defeating fragment penetration remains a high priority, momentum transfer to the vehicle and crew cannot be overlooked as an injury mechanism. The objective of the current study is to devise and execute an evaluation methodology for the seats featured in the MRAP-1 (Mine Resistant Ambush Protected) vehicles in a controlled laboratory environment.

The MRAP vehicles can be divided into two categories; the first category is a shorter version featuring four troop positions and two driver/commander positions. The second category allows for eight troop positions and two driver/commander positions.

This seating evaluation includes seats from five different MRAP variants. In most cases, the vendor has contracted out the seat manufacture and simply integrated the seat into the vehicle. Restraints can be a native part of the seat system or an accessory selected by the vehicle manufacturer. The vehicles featured the same seats in both their category 1 and 2 variants, minimizing the number of seats requiring evaluation. Within a given vehicle the troop station seats were homogeneous; as were the driver & commander station seats (Fig. 1).

Fig. 1, Seats in MRAP vehicle

Of the ten seats tested, 3 possessed design characteristics intended specifically to absorb energy from a high transient impulse. The remaining seven seats depended on conventional seat construction, i.e. upholstery to provide the shock isolation. One seat was developed as a helicopter crash seat and selected for it's proven shock isolation performance while the rest were

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intended for ground vehicles. The seats' boundary conditions as attached in their respective vehicles ranged from relatively rigid attachment directly to the sidewall, or flexible attachment via cantilever beams or ropes.

The magnitude and frequency of mechanical shock experienced in the field varies greatly and depends mainly on the characteristics of the threat impulse and the structural response of the vehicle. It is therefore unsuitable to compare the merits of seats based on limited live-fire test data. ARL's mechanical shock facility employs several shock machines with the capability of testing seated crew members to range of levels and durations.

2. METHODS

A fixture was designed for each seat that would best replicate the seat's boundary condition in the vehicle. Seats that were floor mounted were attached to a robust, aluminum fixture that was attached to the shock machine platform. Seats that were attached at the back were fitted to vertical fixture of similar construction. Two variations of a wall mounted seat were tested, requiring a fixture that represented the proper floor-ceiling dimension in the vehicle. If the seat employed cab-anchored seatbelts they were anchored to equivalent landmarks on the test fixture.

All vertical tests were performed on the vertical shock machine (Lansmont, Inc., Monterey, CA) which has a table measuring 25 inches by 32 inches and can accommodate specimens up to 600 pounds. The impulse delivered to the test specimen can be altered using different arrangements of elastic programmers positioned beneath the platform (Figure 2).

Fig. 2, Lansmont vertical shock machine (left), ATD seated on shock machine (right)

The vertical shock machine was operated in free-fall mode to avoid storing energy in the test specimen. Operating the machine in accelerated mode would cause the test specimen to 'decompress', creating unrealistic initial conditions. All data was sampled and filtered according to conventions used by the Army test community (Alem, 1997).

Each seat's shock isolation capacity was determined by performing a series of tests that would span the threshold response of the occupant. These test levels ranged from 3-9 m/s and were produced from drop heights of 20-70 inches. All tests produce a single-sided half-sine acceleration pulse of a constant, 6 ms duration (Fig. 3)

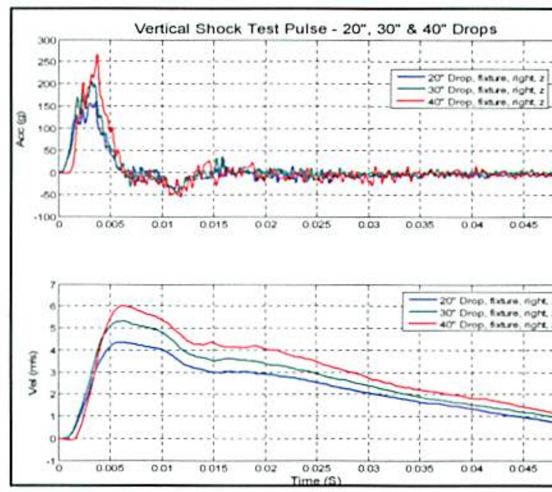

Fig. 3, Vertical shock test pulses

A different shock machine was required to perform lateral shock tests on the seated crewmember. ARL's horizontal shock machine (Lansmont, Inc., Monterey, CA) provided a repeatable input to the seat with zero pre-acceleration (Fig. 5). The machine is pneumatically actuated and the pulse duration is controlled using the same programmers used in the vertical shock machine.

The horizontal tests can be divided into three categories:

1. Lateral (driver/commander seats)
2. Frontal (troop seats)
3. Rear (troop seats)

The different seat types (driver/commander, troop) were tested based on the field test conditions and the impulses the vehicles would be expected to experience. According to the vehicle coordinate system (Fig 4), underbody and perimeter positioned threats would not produce significant x-direction responses. The threat conditions were expected to result in significant loads in the y, z-directions only. Given the arrangement of driver/commander and troop seats in the vehicle, these significant impulses would equate to lateral (side to side) impulse for the driver/commander station (facing forward), and a frontal/rear impulse to the troop station (facing inboard). Only one vehicle variant troop seat was configured facing forward. Instead of performing incrementally higher tests until the response threshold was reached, all horizontal tests were performed at a low level ΔV of 5 m/s and a high level of 9 m/s. Hardware stock concerns limited the number of tests that could be executed, and preliminary analysis of the data suggested a threshold level response would be unattainable.

Fig. 4, Vehicle coordinate system

The 50th percentile THOR-NT ATD (GESAC, Inc.) was used in this evaluation. The THOR-NT is the most biofidelic frontal crash mannequin in production, and has several advantages over the Hybrid III. The THOR spine was designed to behave more realistically with the addition of rubber segments in the lumbar and cervical spine. Additionally, a more biofidelic pelvis shape is used in the THOR. The ATD was outfitted with the following soldier gear: helmet, combat boots, battle dress uniform, flak jacket and front, back and side armor plates. The tested weight of the ATD was 215 pounds.

In each vertical test, the ATD's feet were supported on the test platform so that the feet experienced the same input as the seat. No attempt was made to simulate dynamic deflection of the floor.

The ATD response of interest for vertical tests was the vertical pelvis acceleration. Prior studies of the ATD response to vertical shock showed responses from other parts of the body to be significantly below threshold when compared to pelvis threshold levels. The pelvis acceleration was used to compute the Dynamic Response Index (DRI), both of which are used by the Army test community for injury assessment (Stech, et al., 1969),. These responses were compared to criteria and normalized to the threshold level of 17.7 (NATO Task Group 25, 2007). Due to decoupling of the ATD from the seat, the horizontal test responses were limited to peak relative head excursion (Fig. 5). This measure was calculated via video post-processing and can be used to infer likelihood of crew-cabin interaction. The excursion measure was corrected for variation in input ΔV.

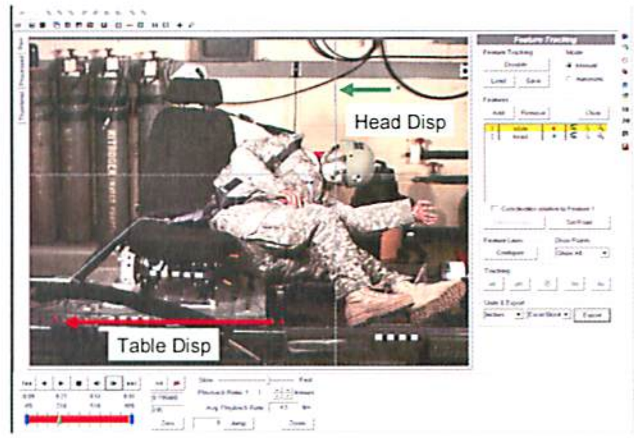

Fig. 5, Peak relative head excursion measurement

3. RESULTS

Vertical test results indicate the range of input ΔV at which the DRI threshold is reached to be 5.8-7.8 m/s with an average of 6.75 m/s and standard deviation of +/- 0.62 m/s. If the ATD is rigidly coupled to the impulse, meaning the seat offers no shock absorption, the DRI to ΔV relationship will be approximately 4:1, so that the input at the DRI threshold level of 17.7 would be approximately 4.4 m/s.

The high level lateral test results indicate the range of peak relative head excursion to be from 14.4-30 inches. The average excursion was 21.4 inches with standard deviation of +/- 5.9 inches. Additional post-processing of the high speed video revealed the peak excursion value correlated directly to the peak head CG velocity.

4. CONCLUSIONS

The three seats using dedicated energy absorbing sub-assemblies had an average impulse tolerance of 6.9 m/s compared to 6.6 m/s for those without such components. Average peak head excursion for lateral tests was higher for seats with 4-point restraints than 5-point restraints, 23.9 inches and 16.3 inches, respectively.

Potential shortfalls of the current methodology include differences in kinematics of a drop test versus a blast-off test. While both events are present in the engagement, a drop test cannot create the same initial conditions experienced in blast-off. The contribution of local response to the ATD legs is also a shortcoming of the current test apparatus. In summary, a method for evaluating the vertical shock isolation capacity of military seating systems was proposed and executed. This methodology will result in more adequate seating and improved overall survivability.

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REFERENCES

NATO Task Group 25., 2007: Test Methodology for Protection of Vehicle Occupants against Anti-Vehicular Landmine Effects, TR-HFM-090.

Alem, N., 1997: Mine Blast Acceleration Injury Assessment: Methods Criteria and Software. USAARL Report No. 97-28.

Stech, E.I., Payne P.R., 1969: Dynamic Models of the Human Body. AMRL-TR-66-157.