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Impact Protection Properties of Candidate Foam Inserts for the Personnel Armor System for Ground Troops (PASGT) Helmet System

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Operational paratrooper head injuries increased 2-fold relative to other body region injuries from 1985 to 1990. This trend concerned the leaders of the U.S. Army paratrooper community, primarily XVIII Airborne Corps and U.S. Army Infantry School, who directed development of head protective measures without modification of the ballistic helmet shell. They established a goal of 50 percent reduction of transmittance of impact forces to the paratrooper head. The outcome was to conserve the fighting strength through reduction of head injuries during airborne operations.

We tested a prototype foam insert for the Personnel Armor System for Ground Troops (PASGT) helmet system. The helmet with and without inserts was tested using standard head impact tests.

The prototype foam inserts used in testing did not meet the desired 50 percent reduction in headform acceleration. The foam inserts did improve the helmet's impact absorption
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capabilities by an average of 23.8 percent for initial impacts and 13.3 percent for subsequent impacts. The degree to which this reduced force transmission would reduce head injury could not be predicted.

Table of contents

List of tables

List of figures

Military relevance

Operational paratrooper head injuries increased twofold relative to other body region injuries from 1985 to 1990 (Sadlowski, 1990). This trend concerned the leaders of the U.S. Army paratrooper community, primarily XVIII Airborne Corps and U.S. Army Infantry School, who directed development of head protective measures without modification of the ballistic helmet shell. They established a goal of 50 percent reduction of transmittance of impact forces to the paratrooper head. The outcome was to conserve the fighting strength through reduction of head injuries during airborne operations (Shanahan, 1990).

Background

The U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, completed an epidemiologic survey of head injuries among paratroopers for the period 1985 to 1989. Among 277 paratroopers suffering reported head injuries during airborne operations with at least one lost work day, there were four fatalities. The high risk zone for injury was around 10 to 20 jumps, and then gradually declined with advancing experience. Most injuries occurred in the landing phase (77.8 percent). Among the 161 injuries with defined injury locations, 89.4 percent involved concussion or contusion of the brain. The authors detailed additional background information on the biodynamics of airborne operations (Paschal et. al, 1990).

For the Personnel Armor System for Ground Troops (PASGT) program, USAARL, in coordination with the Natick Research, Development, and Engineering Center, Natick, Massachusetts, tested two PASGT paratrooper helmets fitted with prototype 0.25 inch thick foam inserts. The insert group consisted of three pads placed between the standard helmet suspension assembly, to include the nape shock pad, and the inside aspect of the ballistic protection shell. Each pad was placed along the coronal plane covering the frontal aspect, crown and parietal aspect of the skull. The pads were intended to be easy to insert, remove, and maintain, durable in the operational environment, withstand multiple impacts, and stable enough after insertion to avoid loss during airborne operations. USAARL was tasked to determine the capability of the foam insert to reduce test headform accelerations during impact tests.

Methods

The impact test were conducted on a vertical monorail drop tower assembly. PASGT helmets were placed on the test headform, raised to a height of 30 inches, and released. The hemispherical impact anvil was used for all tests. Impact velocity was measured just prior to helmet impact. Headform acceleration was measured with a single axis accelerometer located near the headform's mass center. Impacts were performed at five different sites. These sites included the front, back, right, left, and crown.

Two PASGT helmets configured with "Volara Type A" foam inserts were impact tested. The two helmets were designated "A" and "B" respectively. Helmet "A" was impact tested four times at all five impact sites (a total of 20 impacts) with the same foam insert installed for each impact. Helmet "B" was impact tested four times at all five impact sites (a toal of 20 impacts) with a new set of foam inserts installed for each impact series. This was done to determine if multiple impacts caused performance degradation of the foam.

A fifth impact test series was conducted on both helmets configured to the standard PASGT paratrooper helmet. This configuration does not include the "Volara Type A" foam inserts. This test series was performed to provide typical helmet performance data.

Results

Figure 1 shows a representative test result of a PASGT paratrooper helmet without the foam insert. A 200 Hz, 4-pole, low-pass Butterworth filter was applied to the output. The peak acceleration was 170 G. In contrast, Figure 2 shows the results of an equivalent test except the PASGT helmet had the foam insert in place. The peak acceleration was 148 G. This represents a 12.9 percent reduction in headform acceleration with the foam insert.

The test results are summarized in Tables 1, 2, and 3. The standard PASGT paratrooper helmet configuration test results are provided in Table 1. The initial impacts from helmet "A" are included with the results from helmet "B" and are summarized in Table 2. The subsequent impact results obtained with helmet "A" are summarized in Table 3. There was an average 23.8 percent reduction in headform acceleration with the addition of the foam inserts when compared to helmet impacts without inserts.

Table 1.
Summary test results, standard PASGT paratrooper helmet configuration.

Impact location	Average peak G	Standard deviation	Sample size
Front	218.15	22.27	2
Rear	269.05	22.84	2
Side	173.47	8.48	4
Crown	216.30	22.06	2
All locations	210.09	39.78	10

Table 2.
Summary test results, PASGT paratrooper helmet with inserts, initial impacts.

Impact location	Average peak G	Standard deviation	Percent reduction*	Sample size
Front	161.24	14.28	26.1	5
Rear	196.00	40.24	27.1	5
Side	162.39	27.72	6.4	10
Crown	118.72	6.42	45.1	5
All locations	160.15	35.02	23.8	25

* Percent reduction is relative to the standard PASGT paratrooper helmet test results.

Table 3.
Summary test results, PASGT paratrooper helmet with inserts, subsequent impacts.

Impact location	Average peak G	Standard deviation	Percent reduction*	Sample size
Front	184.90	1.15	15.2	3
Rear	190.43	8.36	29.2	3
Side	182.88	19.62	-5.4	5
Crown	170.23	5.44	21.3	3
All locations	182.22	13.58	13.3	14

* Percent reduction is relative to the standard PASGT paratrooper helmet test results.

For all helmet configurations, the impact site with the highest reading was the rear where the standard foam rubber pad is located. The next highest readings were the front, sides, and crown, respectively. No difference was found between the left and right sides. This site location trend may be attributed to the contact area between the helmet and headform at the point of impact. The rear and frontal impact areas have the smallest contact areas while the sides and crown have a greater impact area. To compensate for these performance variations in impact locations, the foam insert pad's thickness or density could be increased to counteract the effects of a reduced contact area. The impact protective influence of the standard foam rubber pad at the rear of the helmet is undiscernible from these results.

Subsequent impacts with the same foam inserts resulted in higher "G" readings than the initial impacts, indicating a material structure change (Tables 2 and 3). This change is due to a permanent set in the foam as a result of the initial impact, an insufficient foam recovery time between tests, and/or a change in the helmet fit to the test headform (i.e. headband and cross strap adjustments, or webbing stretch). The subsequent tests were conducted within minutes of each other. This is a realistic event since multiple head impacts may occur during parachute landing falls. The differences in "G" readings between the 2nd, 3rd, and 4th impacts were insignificant. The average "G" level for the subsequent impacts was still 13.3 percent lower than the impacts without foam inserts. After an initial impact, the foam inserts provide increased protection over not having the foam inserts.

Conclusion

This study showed that the prototype foam inserts used in testing did not meet the desired 50 percent reduction in headform acceleration. The foam inserts did improve the helmet's impact absorption capabilities by an average of 23.8 percent for initial impacts and 13.3 percent for subsequent impacts. The degree to which this reduced force transmission would reduce head injury could not be predicted.

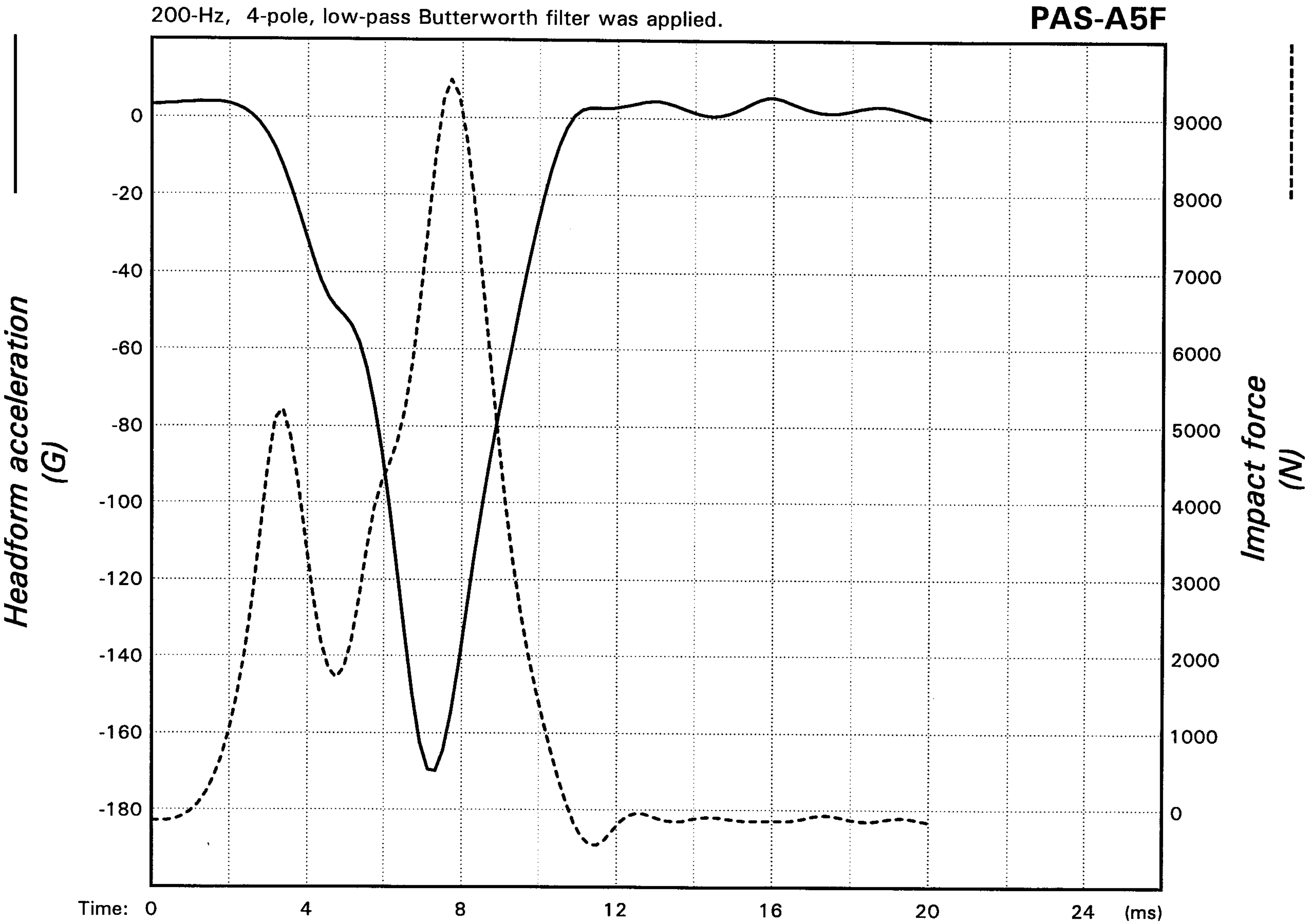

Figure 1. Test results of PASGT paratrooper helmet without foam insert, frontal drop 55 degrees off vertical.

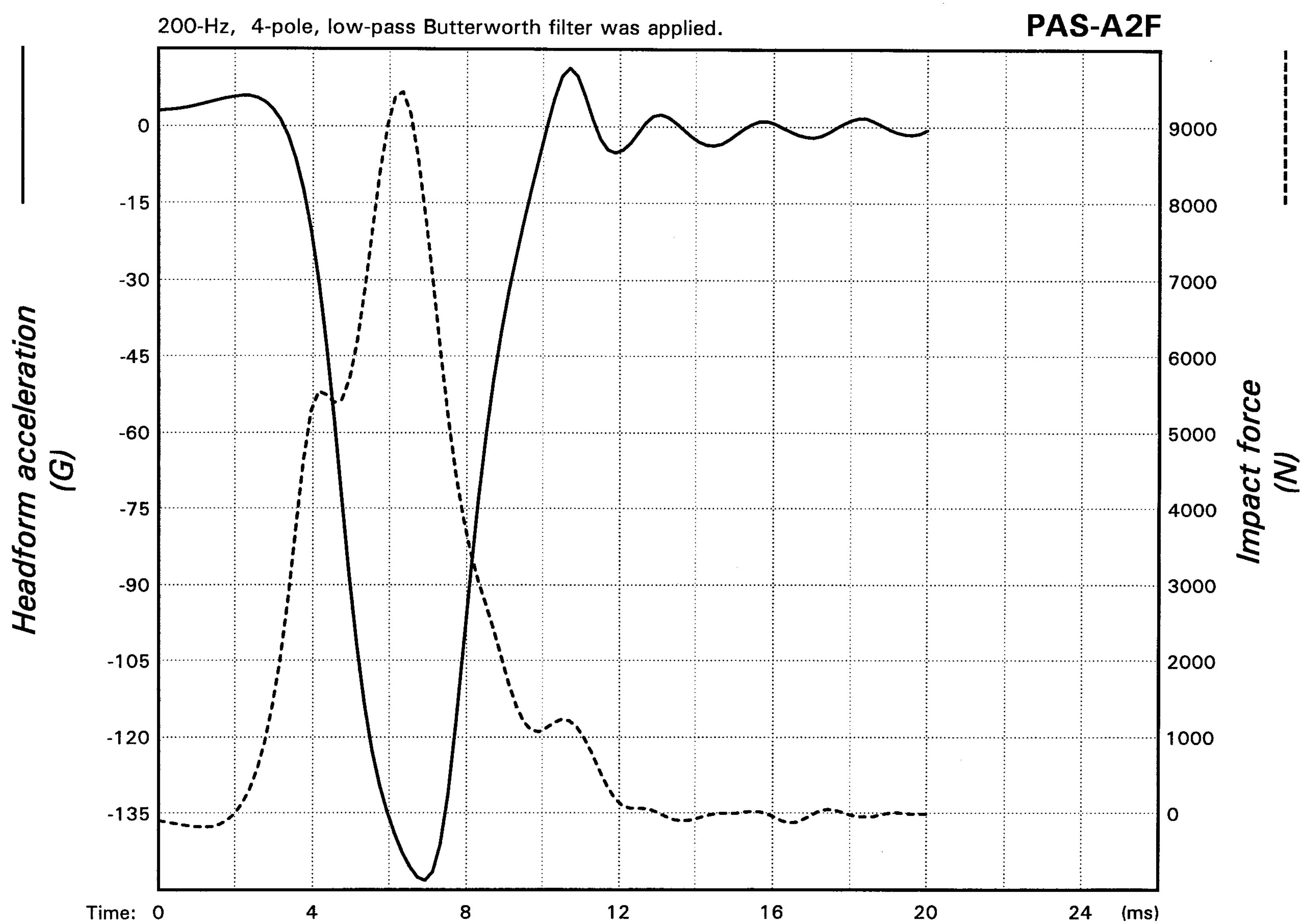

Figure 2. Test results of PASGT paratrooper helmet with foam insert, frontal drop 55 degrees off vertical.

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