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Evaluating the Potential for Rotation and Loss of Flight Helmets From Inertia and Impact Loads

(Reprint)

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and

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Evaluating the Potential For Rotation and Loss of Flight Helmets From Inertia and Impact Loads

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ABSTRACT *In severe helicopter accidents, flight helmets rotate or sometimes come off the head, triggering wearer injury. This study evaluates rotation potential for new flight helmets. Current and prototype flight helmets (SPH-4B and two version of the HGU-56) were subjected to three tests. First, rotation was measured with up to a 50-pound upward pull at the rear edge of the helmet on a medium size headform. Second, angular displacement was measured with a 30 pound force at the side of the helmet. Third, the helmet was placed on a Hybrid II headform and Hybrid III neck, then mounted on a pendulum test device. The freefalling pendulum was decelerated to produce 16 to 20 G peak acceleration at the neck. Angular displacement of the helmet versus time was measured with high speed video.*

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The test series resulted in the selection of an improved HGU-56 design by the helmet developer. These tests may be improved by the use of more severe dynamic tests in the future to better reproduce severe impact conditions.

INTRODUCTION

Although flight helmets were scorned by some early safety authorities[1], Graeme Anderson reported in his 1919 aviation medicine text that of 58 training accidents in his experience, head protection saved student pilots from head injuries in 15.[2] Crowley studied survivable U.S. Army helicopter accidents from 1972-88 and found that the risk of fatal head injury was 6.3 times greater in unhelmeted occupants compared with those wearing the SPH-4 ($p<0.01$).[3]

The United States Army Aeromedical Research Laboratory (USAARL) evaluates aviation life support equipment (ALSE) retrieved from aircraft accidents. USAARL studies ALSE to correlate wearer injuries with the equipment performance. In 1984, Reading et al reported that 21 percent of the helmets in the USAARL database came off the wearer's head during the crash sequence. Chinstrap failure caused 63% of the helmet losses while failure or excessive stretching of the retention system accounted for the remainder.[4] In a later USAARL study by Vymwy-Jones et al, 18 of 60 flight helmets came off the wearer's head during the mishap. In this group of helmets, there were 11 chinstrap failures and 20 helmets with retention system damage. This study also found that the injuries were more severe for wearers that suffer excess rotation or loss of their flight helmet.[5]

These USAARL studies resulted in improvements to the retention system for Army flight helmets. The chinstrap of the original SPH-4 was upgraded in 1982 to include a dual-snap closure. The chinstrap was further improved when it was replaced with a stronger "yoke" chinstrap (440 lb vs 300 lb tensile strength and 1" vs 3" stretch) in the SPH-4B flight helmet. The strength of the chinstrap is tested by pulling the chinstrap with a prescribed load for 2 minutes and measuring the elongation. The chinstrap fails if there is excess elongation (typically > 1 to 1.5 inches) or it separates. In addition, the sling suspension assembly in the SPH-4 has been replaced with a thermoplastic liner in the SPH-4B.[6]

Despite these enhancements and standard qualification tests, flight helmets are still subject

to rotation and loss in aircraft mishaps. For example, in a recent mishap all twelve occupants of an MH-60, including the lone survivor, lost their helmet when the aircraft struck water. This occurred despite the fact that four aircraft occupants were wearing the newer SPH-4B helmets.

The purpose of this study was to investigate new tests to detect the design features of existing and prototype flight helmets that prevent rotation or loss in an aircraft accident. This data was needed to guide selection of an improved retention system for the new Aircrew Integrated Helmet System (AIHS), now designated the Head Gear Unit number 56 for Personnel (HGU-56/P).

MATERIALS AND METHODS

FLIGHT HELMETS

The SPH-4B and two different versions of the new HGU-56/P were selected for testing. The size regular SPH-4B flight helmet includes a thermoplastic liner, enhanced yoke assembly, and chinstrap secured with D-rings. The two HGU-56/P flight helmets included thermoplastic liners and chinstraps secured with D-rings.

The standard HGU-56/P includes a stiff plastic plate in the back of the helmet which forces the head forward when straps behind the plate are tightened. This "nape plate" rests on the back of the head, above the occipital ridge of the skull. The earcups are fixed to the outer shell with velcro (figure 1).

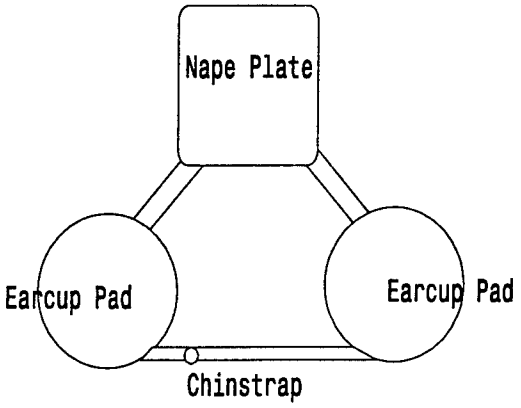

Figure 1. Nape plate and retention straps in original HGU-56/P flight helmet.

The revised HGU-56/P has a new retention system with a soft nape plate that form fits to the back of the skull, below the occipital ridge (figure 2). The velcro has been removed from the shell at the earcups and nylon straps run below the earcups to join the nape adjustment strap to the chinstrap. When the nape strap is tightened, the nape strap, side straps, and chinstrap form a ring around the base of the skull at the upper neck.

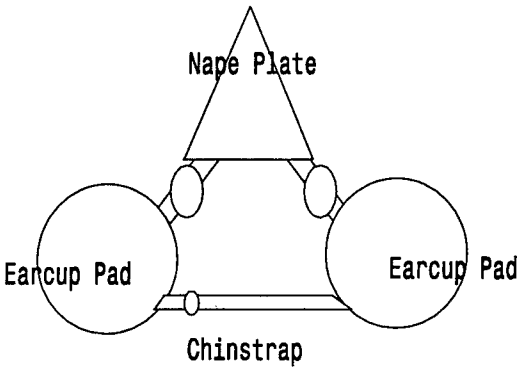

Figure 2. Nape strap and retention straps in improved HGU-56/P flight helmet.

ROTATION TESTS

Forward rotation of the helmet (about the lateral y-axis) in response to inertia was simulated by pulling upward on the rear edge of the helmet shell. The test helmet was placed on a 50th percentile military pilot headform rigidly mounted. A spring scale was used to pull on a small hook placed at the rear edge of the helmet shell. The forward rotation of the helmet was measured in response to pulling forces up to 50 pounds.

Sideward displacement of the helmet (about the vertical z-axis) in response to impact on the side of the helmet was simulated by pulling on the side of the helmet shell. The test helmet was mounted on the same 50th percentile headform. A spring scale was used to push at the edge of the helmet shell along the visor cover. The angular displacement of the helmet was measured in response to forces up to 30 pounds.

Dynamic testing of retention was performed by mounting each helmet on a Hybrid II headform, attached to a Hybrid III neck simulator, and placed at the end of a 6-foot pendulum arm (figure 3). The pendulum was allowed to freefall

through a vertical distance of 3.32 feet and was stopped by a foam block. The pendulum deceleration produced a 16 to 20 G deceleration force measured at the base of the neck simulator. High speed (1000 f/s) video frames were reviewed to measure the rotation of the helmet for each 10 ms time increment.

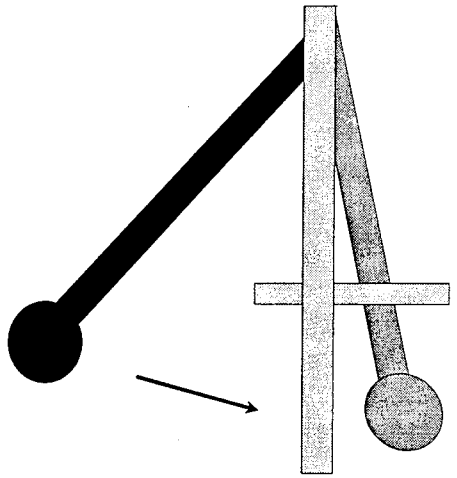

Figure 3. Schematic of pendulum test device.

RESULTS

The forward rotation of the helmets in response to a 50 pound force applied to the rear edge of the helmet shell varied from 18 to 33 degrees as shown in figure 4. The 30 pound force applied to the side of the visor resulted in 13 to 21 degrees of sideward rotation as shown in figure 5. The dynamic test produced forward and rearward rotation of the helmet as the neck flexed forward and back. The dynamic response of each helmet, measured by the rotation of the helmet relative to the headform, is shown in figure 6.

DISCUSSION

The most important factor in helmet retention is providing a chin strap and nape strap entity that will not stretch or tear in response to impact loads. USAARL has not seen a 440-pound tensile strength chin strap severed or separated in a survivable accident.

Compliant and stretchable materials are used to form the retention system and protective parts of most flight helmets. It is the stretching and compression of the retention system and internal foams that contributes to loss of helmets. For the

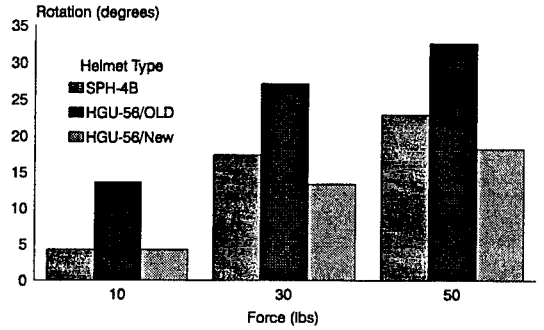

Figure 4. Forward rotation of helmets in response to force at rear edge of helmet.

helmet to dislodge from the head, there must be a large enough opening at the base of the helmet for the head to pass out of the helmet. The SPH-4B use a chin strap that is contiguous with material below the earcups and the nape strap to form a "ring" or "noose" around the neck. The circumference of this ring ultimately limits

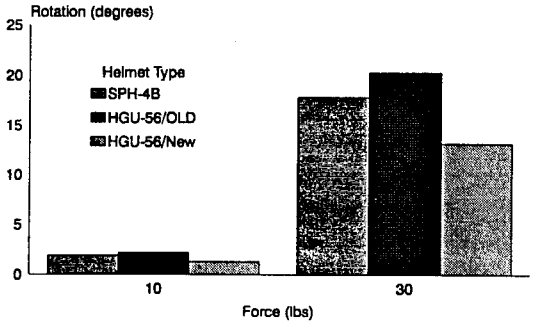

Figure 5. Sideward rotation of helmets in response to force at side of helmet visor.

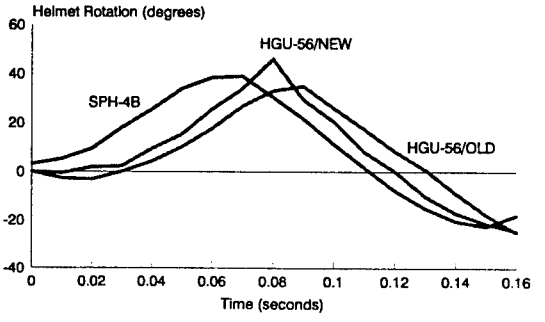

Figure 6. Forward and rearward rotation of the helmet on the head in response to dynamic impact simulation.

forward rotation and loss of the helmet. If the circumference of the "noose" is smaller than the circumference of the head, the helmet cannot rotate forward off the head. The original HGU-56/P configuration did not provide a separate nape strap or straps below the earcups. There was no ring of material around the neck to resist forward rotation. This resulted in the excess rotation and high potential for loss of this helmet. The new version of the HGU-56/P includes a separate nape strap that attaches to straps below each earcup. This forms a ring at the base of the neck and accounts for the superior performance of this design.

While the tests described in this paper assisted in evaluating the retention systems of these helmets, additional refinement of the test methods is required. We feel that greater loads should be placed on the back and sides of the helmet to better represent impacts in severe but survivable accidents. The torque applied in the horizontal plane to each helmet varies with the helmet diameter, but this variation simulates comparable torque applied to helmets with different diameters in actual crashes with tangential impacts.

CONCLUSIONS

The static and dynamic tests of the retention systems in Army flight helmets assisted in selection of an improved retention system for the HGU-56/P. Further refinement of retention tests may be needed to better simulate inertia and impact forces in survivable accidents.

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