The Airbag as a Supplement to Standard Restraint Systems in the AH-1 and AH-64 Attack Helicopters and Its Role in Reducing Head Strikes of the Copilot/Gunner

By

Nabih M. Alem
Dennis F. Shanahan
John V. Barson

Biodynamics Research Division

and

William H. Muzzy, III

Naval Biodynamics Laboratory
New Orleans, Louisiana

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United States Army Aeromedical Research Laboratory
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Reviewed:

DENNIS F. SHANAHAN
LTC, MC, MFS
Director, Biodynamics Research Division

Released for publication:

ROGER W. WILLEY, C.D., Ph.D.
Chairman, Scientific Review Committee

DAVID H. KARNEY
Colonel, MC, SFR
Commanding
The airbag as a supplement to standard restraint systems in the AH-1 and AH-64 attack helicopters and its role in reducing head strikes of the copilot/gunner, Volume II

Accident investigation records of U.S. Army helicopter crashes show injuries of pilots due to striking a structure inside the cockpit outnumber those due to excessive accelerations by a five-to-one ratio. This two-volume report presents the results of a study of the effectiveness of airbags in reducing the severity of contact injury to the gunner when striking the gunsight. Airbag systems were installed on the gunsights in simulated Cobra and Apache cockpits, then sled tested at 7 and 25 g. The tests indicated airbags reduced head accelerations by 65 percent, head injury criteria by 77 percent, and head angular acceleration by 76 percent in the Cobra tests. In the Apache tests, the airbags reduced those same indicators by 68, 52, and 83 percent. An airbag system, the report concludes, is likely to prevent severe or fatal head and chest injuries in an Apache or Cobra crash.

Volume 1 of the report describes the tests and discusses the results. Volume 2 consists of Appendixes A, B, and C of the report and contains processed signal graphs of all sled tests.
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Appendix A

This appendix contains the processed transducer signals from the 11 (Cobra) telescopic sighting unit (TSU) tests with inertia reels and without airbags.

These include eight tests (LX6196 - LX6204) conducted during the first phase of testing and three tests (LX6274 - LX6276) which were run in the second phase.

Figures A-1 thru A-11 show the sled acceleration pulses and computed velocity and jerk signals for the 11 tests.

Figures A-12 thru A-22 display available components and resultants head linear accelerations.

Figures A-23 thru A-33 display the head roll acceleration signals and computed angular velocities and displacements.

Figures A-34 thru A-44 show the head pitch acceleration signals and computed angular velocities and displacements.

Figures A-45 thru A-55 display the amounts of belt extension and the computed velocities and accelerations.
Appendix A

1. LX6196
2. LX6197
3. LX6198
4. LX6199
5. LX6200
6. LX6201
7. LX6203
8. LX6204
9. LX6274
10. LX6275
11. LX6276
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Figure A-4. Sled acceleration signal and its computed velocity and jerk for test LX6199.
Figure A-5. Sled acceleration signal and its computed velocity and jerk for test LX6200.
Figure A-6. Sled acceleration signal and its computed velocity and jerk for test LX6201.
Test: LX6203

maxima: 25.04 G 12.32 m/s 3066 G/s
minima: -1.33 .00 -1334

Figure A-7. Sled acceleration signal and its computed velocity and jerk for test LX6203.
Test: LX6204

maxima: 25.03 G 12.33 m/s 3069 G/s
minima: -1.50 .00 -1310

Figure A-8. Sled acceleration signal and its computed velocity and jerk for test LX6204.
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Figure A-15. Three components and resultant of the linear head acceleration for test LX6199.
Figure A-16. Three components and resultant of the linear head acceleration for test LX6200.
Test: LX6201

maxima:
- 10.5 Gx
- 2.0 Gy
- 19.8 Gz

minima:
- -29.7
- -7.9
- -43.9

Figure A-17. Three components and resultant of the linear head acceleration for test LX6201.

Peak = 49.8 G
H.I.C. = 245
T1 = 86.5 ms
T2 = 122.8 ms
Test: LX6203

maxima: 0 Gx 0 Gy 138.3 Gz
minima: 0 0 -83.4

Figure A-18. Three components and resultant of the linear head acceleration for test LX6203.
Figure A-19. Three components and resultant of the linear head acceleration for test LX6204.
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Test: LX6200

maxima: 397 rad/s/s 1.1 rad/s 0 deg
minima: -387 -3.4 -10

Displacement (deg)

Velocity (rad/s)

Roll acceleration @ X (rad/s/s)

Time: 0 40 80 120 160 200 (ms)

Figure A-27. Head roll angular acceleration, velocity, and displacement signals for test LX6200.
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Figure A-39. Head pitch angular acceleration, velocity, and displacement signals for test LX6201.
Test: LX6203

maxima: 6507 rad/s, 28.2 rad/s, 29 deg
minima: -10462, -50.5, -106

Figure A-40: Head pitch angular acceleration, velocity, and displacement signals for test LX6203.
Figure A-41. Head pitch angular acceleration, velocity, and displacement signals for test LX6204.
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Figure A-48. Amount of belt extension and the velocity and acceleration of extension for test LX6199.

Test: LX6199
maxima: 11.4 cm 119.32 m/s 1672.9 G
minima: -103.8 -109.83 -1703.8
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Appendix B

This appendix contains the processed transducer signals from the 11 AH-64 (Apache) optical relay tube (ORT) tests with inertia reels and without airbags.

These include 10 tests (LX6208 - LX6217) conducted during the first phase of testing and one test (LX6277) which were run in the second phase.

Figures B-1 thru B-11 show the sled acceleration pulses and computed velocity and jerk signals for the 11 tests.

Figures B-12 thru B-22 display components and resultants head linear accelerations.

Figures B-23 thru B-33 display the head roll acceleration signals and computed angular velocities and displacements.

Figures B-34 thru B-44 show the head pitch acceleration signals and computed angular velocities and displacements.

No belt extension signals were available for these tests.
Appendix B

1. LX6208
2. LX6209
3. LX6210
4. LX6211
5. LX6212
6. LX6213
7. LX6214
8. LX6215
9. LX6216
10. LX6217
11. LX6277
Figure B-1. Sled acceleration signal and its computed velocity and jerk for test LX6208.
Figure B-2. Sled acceleration signal and its computed velocity and jerk for test LX6209.
Figure B-3. Sled acceleration signal and its computed velocity and jerk for test LX6210.
Test: LX6211

maxima: 6.76 G 10.71 m/s 819 G/s

minima: -.55 .00 -217

Time: 0 100 200 300 400 500 (ms)

Figure B-4. Sled acceleration signal and its computed velocity and jerk for test LX6211.
Figure B-5. Sled acceleration signal and its computed velocity and jerk for test LX6212.
Figure B-6. Sled acceleration signal and its computed velocity and jerk for test LX6213.
Figure B-7. Sled acceleration signal and its computed velocity and jerk for test LX6214.
Figure B-8. Sled acceleration signal and its computed velocity and jerk for test LX6215.
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Figure B-14. Three components and resultant of the linear head acceleration for test LX6210.
Figure B-15. Three components and resultant of the linear head acceleration for test LX6211.

Peak = 39.9 G
H.I.C. = 51
T1 = 148.9 ms
T2 = 159.8 ms
Figure B-16. Three components and resultant of the linear head acceleration for test LX6212.
Figure B-17. Three components and resultant of the linear head acceleration for test LX6213.
Figure B-18. Three components and resultant of the linear head acceleration for test LX6214.
Figure B-19. Three components and resultant of the linear head acceleration for test LX6215.
Figure B-20. Three components and resultant of the linear head acceleration for test LX6216.
Test: LX6217

maxima: 3.2 Gx  3.0 Gy  15.6 Gz

minima: -10.8 -1.9 -4.3

Figure B-21. Three components and resultant of the linear head acceleration for test LX6217.
Figure B-22. Three components and resultant of the linear head acceleration for test LX6277.
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Figure B-27. Head roll angular acceleration, velocity, and displacement signals for test LX6212.
Figure B-28. Head roll angular acceleration, velocity, and displacement signals for test LX6213.
Figure B-29. Head roll angular acceleration, velocity, and displacement signals for test LX6214.
Figure B-30. Head roll angular acceleration, velocity, and displacement signals for test LX6215.
Figure B-31. Head roll angular acceleration, velocity, and displacement signals for test LX6216.
Figure B-32. Head roll angular acceleration, velocity, and displacement signals for test LX6217.
Figure B-33. Head roll angular acceleration, velocity, and displacement signals for test LX6277.
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Figure B-35. Head pitch angular acceleration, velocity, and displacement signals for test LX6209.
Figure B-36. Head pitch angular acceleration, velocity, and displacement signals for test LX6210.
Figure B-37. Head pitch angular acceleration, velocity, and displacement signals for test LX6211.
Figure B-38. Head pitch angular acceleration, velocity, and displacement signals for test LX6212.
Figure B-39. Head pitch angular acceleration, velocity, and displacement signals for test LX6213.
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Figure B-41. Head pitch angular acceleration, velocity, and displacement signals for test LX6215.
Figure B-42. Head pitch angular acceleration, velocity, and displacement signals for test LX6216.
Figure B-43. Head pitch angular acceleration, velocity, and displacement signals for test LX6217.
Figure B-44. Head pitch angular acceleration, velocity, and displacement signals for test LX6277.
Appendix C

This appendix contains processed transducer signals from 11 tests where an airbag was mounted below the gunsight to supplement the standard restraint system in the Cobra and Apache.

These include five Cobra tests (LX6269 thru LX6273) and six Apache tests (LX6278 thru LX6283) which were all conducted in the second phase of testing.

Figures C-1 thru C-11 show the sled acceleration pulses and computed velocity and jerk signals for the 11 tests. Note for test LX6269, the sled pulse was the only transducer signal that was available for processing.

Figures C-12 thru C-21 display components and resultant head linear accelerations.

Figures C-22 thru C-31 display the head roll acceleration signals and computed angular velocities and displacements.

Figures C-32 thru C-41 show the head pitch acceleration signals and computed angular velocities and displacements.

Figures B-42 thru A-51 display the amounts of belt extension and the computed velocities and accelerations.
Appendix C

1. LX6269
2. LX6270
3. LX6271
4. LX6272
5. LX6273
6. LX6278
7. LX6279
8. LX6280
9. LX6281
10. LX6282
11. LX6283
Figure C-1. Sled acceleration signal and its computed velocity and jerk for test LX6269.
Figure C-2. Sled acceleration signal and its computed velocity and jerk for test LX6270.
Figure C-3. Sled acceleration signal and its computed velocity and jerk for test LX6271.
maxima: 25.00 G 11.19 m/s 1095 G/s
minima: -.48 .00 -1191

Figure C-4. Sled acceleration signal and its computed velocity and jerk for test LX6272.
Figure C-5. Sled acceleration signal and its computed velocity and jerk for test LX6273.
Figure C-6. Sled acceleration signal and its computed velocity and jerk for test LX6278.
Test: LX6279

maxima: 7.13 G 9.33 m/s 601 G/s
minima: -.42 0.00 -205

Figure C-7. Sled acceleration signal and its computed velocity and jerk for test LX6279.
Figure C-8. Sled acceleration signal and its computed velocity and jerk for test LX6280.
Figure C-9. Sled acceleration signal and its computed velocity and jerk for test LX6281.

Test: LX6281

maxima: 25.54 G 11.26 m/s 1105 G/s
minima: -1.37 0 0 -1620

Sled acceleration (G)

Jerk (G/s)

Velocity (m/s)

Time: 0 80 160 240 320 400 (ms)
Figure C-10. Sled acceleration signal and its computed velocity and jerk for test LX6282.
Figure C-11. Sled acceleration signal and its computed velocity and jerk for test LX6283.
Figure C-12. Three components and resultant of the linear head acceleration for test LX6270.
Test: LX6271

Maxima: 6.4 Gx, 5.6 Gy, 5.0 Gz

Minima: -27.4, -7.0, -33.9

Figure C-13. Three components and resultant of the linear head acceleration for test LX6271.
Test: LX6272

maxima: 2.1 Gx  6.5 Gy  11.3 Gz

minima: -25.1  -4.4  -34.4

Longitudinal

Z-acc. (G)

0

-20

Lateral

Y-acc. (G)

0

-4

Forward

X-acc. (G)

0

-10

Linear resultant

head acceleration (G)

0

8

16

24

32

40

Peak = 42.7 G
H.I.C. = 133
T1 = 83.3 ms
T2 = 138.1 ms

Time: 0  40  80  120  160  200 (ms)

Figure C-14. Three components and resultant of the linear head acceleration for test LX6272.
Figure C-15. Three components and resultant of the linear head acceleration for test LX6273.
Test: LX6278

maxima: 0.8 Gx 2.0 Gy 4.2 Gz

minima: -9.4 -4.5 -12.8

Figure C-16. Three components and resultant of the linear head acceleration for test LX6278.
Figure C-17. Three components and resultant of the linear head acceleration for test LX6279.
Figure C-18. Three components and resultant of the linear head acceleration for test LX6280.
Figure C-19. Three components and resultant of the linear head acceleration for test LX6281.
Test: LX6282

maxima: 9.3 Gx 9.9 Gy 9.0 Gz

minima: -80.7 -10.7 -51.1

Figure C-20. Three components and resultant of the linear head acceleration for test LX6282.
Test: LX6283  
maxima: 7.1 Gx  16.8 Gy  26.7 Gz  
minima: -224.6 -40.4 -115.2  

Figure C-21. Three components and resultant of the linear head acceleration for test LX6283.
Test: LX6270

maxima: 468 rad/s/s  .9 rad/s  0 deg

dimina: -347 -4.1 -12

Figure C-22. Head roll angular acceleration, velocity, and displacement signals for test LX6270.
Figure C-23. Head roll angular acceleration, velocity, and displacement signals for test LX6271.
Figure C-24. Head roll angular acceleration, velocity, and displacement signals for test LX6272.
Figure C-25. Head roll angular acceleration, velocity, and displacement signals for test LX6273.
Figure C-26. Head roll angular acceleration, velocity, and displacement signals for test LX6278.
Figure C-27. Head roll angular acceleration, velocity, and displacement signals for test LX6279.
Figure C-28. Head roll angular acceleration, velocity, and displacement signals for test LX6280.
Figure C-29. Head roll angular acceleration, velocity, and displacement signals for test LX6281.
Figure C-30. Head roll angular acceleration, velocity, and displacement signals for test LX6282.
Figure C-31. Head roll angular acceleration, velocity, and displacement signals for test LX6283.
Figure C-32. Head pitch angular acceleration, velocity, and displacement signals for test LX6270.
Figure C-33. Head pitch angular acceleration, velocity, and displacement signals for test LX6271.
Figure C-34. Head pitch angular acceleration, velocity, and displacement signals for test LX6272.
Figure C-35. Head pitch angular acceleration, velocity, and displacement signals for test LX6273.
Figure C-36. Head pitch angular acceleration, velocity, and displacement signals for test LX6278.
Figure C-37. Head pitch angular acceleration, velocity, and displacement signals for test LX6279.
Figure C-38. Head pitch angular acceleration, velocity, and displacement signals for test LX6280.
Figure C-39. Head pitch angular acceleration, velocity, and displacement signals for test LX6281.
Test: LX6282

maxima: 2163 rad/s/s 13.6 rad/s 13 deg
minima: -4518 -21.1 -2

Figure C-40. Head pitch angular acceleration, velocity, and displacement signals for test LX6282.
Figure C-41. Head pitch angular acceleration, velocity, and displacement signals for test LX6283.
Figure C-42. Amount of belt extension and the velocity and acceleration of extension for test LX6270.
Figure C-43. Amount of belt extension and the velocity and acceleration of extension for test LX6271.
Figure C-44. Amount of belt extension and the velocity and acceleration of extension for test LX6272.
Test: LX6273

maxima: 24.8 cm 6.43 m/s 49.1 G
minima: -.3 -3.49 -23.2

Figure C-45. Amount of belt extension and the velocity and acceleration of extension for test LX6273.
Test: LX6278

maxima:
- 5.5 cm
- 1.02 m/s
- 10.6 G

minima:
- -1.5
- -1.68
- -12.2

Figure C-46. Amount of belt extension and the velocity and acceleration of extension for test LX6278.
Test: LX6279
maxima: 4.9 cm 1.33 m/s 11.6 G
minima: -1.6 -1.69 -15.7

Figure C-47. Amount of belt extension and the velocity and acceleration of extension for test LX6279.
Test: LX6280

maxima: 15.3 cm 5.49 m/s 41.8 G
minima: -.1 -2.62 -24.2

Figure C-48. Amount of belt extension and the velocity and acceleration of extension for test LX6280.
Figure C-49. Amount of belt extension and the velocity and acceleration of extension for test LX6281.
Figure C-50. Amount of belt extension and the velocity and acceleration of extension for test LX6282.
Figure C-51. Amount of belt extension and the velocity and acceleration of extension for test LX6283.