Blast Testing of Visors Used for Humanitarian Demining

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DRDC Suffield

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The tendency is not as strong as expected; both systems reduced false-alarm rates significantly by dual-sensor systems tell us that those systems as dual sensor in terms of FAR can be approximated by the metal detectors are decreasing with depth. Since the GPRs are always used after the metal detectors, the PODs given by the metal detectors are decreasing with depth. The PODs would have higher than the ALIS can. However, the absolute level of FAR is almost the same as shown in Figure 2 (see page 68) and the larger FAR re-
duction is due to a larger number of false alarms given by the metal detector implemented in the Gryphon. Therefore, performances of the whole systems for humanitarian demining can be characterized as almost the same.

Conclusions and Discussion
The results of the test campaign for the dual-sensor systems tell us that those systems reduced false-alarm rates significantly by more than one-half. However, the systems also reduced probability of detections, which must be considered when using the dual systems. Unlike only one-time signals or a vertical slice. The visual interpretation of the sensor and make decisions when operating the ALIS and the Gryphon needed approximately five and nine minutes, respectively, to survey an area of one square meter. It can be roughly estimated that the ALIS may be too three times slower and the Gryphon may be four to five times slower than stand-alone metal detectors. Even if the search speed in this test is slower than for a stand-alone metal detector, it is possible that these dual sensors would accelerate the clearance operation because rejected alarms from metals sensors would accelerate the clearance operation. The systems developed with dual sensors positively correlate with the results, further developments/improvements, such as an automatic-recognition algorithm, are recommended. Fortunately, it was not possible to use stand-alone metal detectors at the same time as a benchmark, making a direct comparison of dual sensors to stand-alone metal detectors unfeasible. However, one can roughly compare the detectors to those from the STEADY trial, taking into account additional metals. The ALIS and the Gryphon needed approximately five and nine minutes, respectively, to survey an area of one square meter. It can be roughly estimated that the ALIS may be two to three times slower and the Gryphon may be four to five times slower than stand-alone metal detectors. Even if the search speed in this test is slower than for a stand-alone metal detector, it is possible that these dual sensors would accelerate the clearance operation because rejected alarms from metals sensors would reduce the need for excavation or could be rapidly excavated. Increased search speed would also multiply these benefits.

Another dual-sensor trial in Germany was carried out in September 2009 by the International Test and Evaluation Program for Humanitarian Demining as head of the ITEP Secretariat. He is currently a consultant to the Federal Office of Defence Technology and Procurement in Germany.

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The authors acknowledge Mr. N. Pavković and Mr. T. V. B. Vondracek from HCR-CTRO for managing the test. We also thank the developers and deminers that participated.

See Endnotes, Page 79

Figure 1: Testing platform and positioning rig. ALL PHOTOS COURTESY OF BGR AUSREDE

By Captain Charlene Fawcett [DRDC Suffield]

In 2007, the Director of the Canadian Centre for Mine Action Technologies received a request to investigate a potentially promising heat-treatment process to extend the operational life of humanitarian-deminers visors through removal of scratches from the field of view. The heat-treatment procedure was developed by undergraduate students as part of a product-design course and was published in The Journal of Mine Action. The author of that article noted that further testing would be required to determine whether the visor properties were adversely affected by the scratch-repair process. In order to allow for an independent assessment of the technique, the authors provided a detailed outline of the procedures in the article that readers could follow independently.

Trial Objectives and Methodology
The objectives of this research was to assess the blast and ballistic performance of deminer visors before and after heat treatment. To ensure compatibility with the original student project, the same type of visors were obtained from Security Dicers Ltd.

Blast Testing of Visors Used for Humanitarian Demining

This article discusses experimental results from blast testing of Security Devices Ltd. polycarbonate visors used by humanitarian deminers. Visors used in the blast testing fell into one of three categories: new visors, manually scratched visors, and scratched and heat-gun-repaired visors. Results show that the visors in all three categories failed to meet the draft international standard for blast testing relevant at the time, that further research is required to establish pressure profiles for the standard charge size being tested, and that the proposed blast treatment method does appear to degrade the blast resistance of the visor used in the test.

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Mate Goša is a Research Scientist at BAM, who previously worked on testing metal de-
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Dieter Gülle is a retired colonel who has worked since 1985 in different positions con-
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Published by JMU Scholarly Commons, 2009

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The visors were placed in three categories for blast and ballistic assessment: new, scratched, and heat-repaired. Following the procedures in the original project as closely as possible, a new visor was scratched by rubbing sand on the outer surface until the visor was opaque, which provided the “scratched” condition. To get the “scratched and heat-repaired” condition, a new visor was scratched as described and then washed and dried in an oven. After cooling, it was treated using a heat gun in the manner described in the students’ original project. The following documents were used as guidance to develop the test methodologies for blast and ballistic assessment:

- “Test Methodologies for Personal Protective Equipment Against Antipersonnel Mines”
- “Ballistic Test Method for Personal Armour Materials and Combat Clothing”
- “Protocols to Test Upper Body PPE Against AP Blast Mines”
- “A Methodology for Evaluating Demining Personal Protective Equipment for Antipersonnel Landmines”

**Blast Assessment**

Extensive research was conducted at DRDC Suffield by Coh et al., between March 1999 and November 2000 (published in 2005) to develop a protocol for testing and evaluation of upper-body AP Blast mine personal protective equipment. The detailed scientific and technical review resulted in a comprehensive understanding of the physics of a mine blast, factors affecting the performance of PPE, and the nature and severity of injuries depending on the deminer’s position at the time of the blast. From those findings a protocol was developed to ensure the repetition of data, good replication of human-body positioning and motion, representative soil characteristics, standardized explosive charges and containers, reference pressure measurement, and relevant data acquisition and processing.

With regard to the physics of an AP mine blast, factors that needed to be controlled included the type of explosive used, the charge container, depth of charge burial, type of soil, distribution of larger soil particles, compaction and moisture content. These parameters contributed to the strength and distribution of the energy of the blast through the soil matrix and expansion of detonation products and soil ejection away from the center of the explosion.

With regard to the performance of the PPE, it was determined that the shape and surface area of the PPE affected how the blast wave and detonation products propagated around it, thereby affecting how the force was transmitted to the person wearing the PPE. Brittle materials were found to break into fragments that could be propelled at high velocity and cause injury to the person.

Since the mid-1990s, anthropomorphic mannequins have been used at DRDC Suffield for testing of PPE survivability against AP mines. The mannequins are chosen to match the body size and weight of human PPE wearers and allow for instrumented gauges to be placed inside for measurement of body motion. In the 2005 Coh study, the position of the deminer in relation to the blast was found to greatly influence injury outcome. Humanitarian deminers often preferred a crouched or kneeling position to a prone position because it improved the field of view, made prodding easier and was less fatiguing. However, from an injury perspective, deminers in a kneeling position experienced more severe injuries from blasts compared to those injured while working in a prone position.

The desire to better control positioning of the mannequin during trials led DRDC Suffield to develop a testing platform and positioning rig. The platform allowed for exact placement of the mannequin a specific distance away from the charge, which was buried to a measured depth in a known quantity of standardized soil. The rig allowed for exact placement and rig placement. The measurement fixtures and reference pressure transducer can be seen to the right of the mannequin.

The Hybrid III anthropomorphic mannequin, 75th-percentile female model was used for all of the testing as it approximates the size of typical Asian deminers more closely than the other Hybrid III mannequins at DRDC Suffield. The posture chosen for these tests is shown to the right of the mannequin.

### Table 1: Visor blast test results.

<table>
<thead>
<tr>
<th>Visor Description</th>
<th>Charge Size</th>
<th>Reference Pressure (psi)</th>
<th>Visor Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>New 1</td>
<td>200g</td>
<td>59.2</td>
<td>Broke</td>
</tr>
<tr>
<td>New 2</td>
<td>100g</td>
<td>33.2</td>
<td>Broke</td>
</tr>
<tr>
<td>New 3 + apron</td>
<td>100g</td>
<td>33.3</td>
<td>Did not break</td>
</tr>
<tr>
<td>New 4 + apron</td>
<td>100g</td>
<td>42.1</td>
<td>Broke</td>
</tr>
<tr>
<td>New 5 + apron</td>
<td>100g</td>
<td>39.1</td>
<td>Did not break</td>
</tr>
<tr>
<td>Baseline established at 75g</td>
<td>32.2</td>
<td>Did not break</td>
<td></td>
</tr>
<tr>
<td>New 6</td>
<td>75g</td>
<td>34.6</td>
<td>Broke</td>
</tr>
<tr>
<td>New 7</td>
<td>75g</td>
<td>34.8</td>
<td>Broke</td>
</tr>
<tr>
<td>New 8</td>
<td>75g</td>
<td>34.8</td>
<td>Broke</td>
</tr>
<tr>
<td>New 9</td>
<td>75g</td>
<td>34.8</td>
<td>Broke</td>
</tr>
<tr>
<td>1A scratched</td>
<td>75g</td>
<td>34.6</td>
<td>Broke</td>
</tr>
<tr>
<td>2A scratched</td>
<td>75g</td>
<td>34.8</td>
<td>Broke</td>
</tr>
<tr>
<td>3A scratched</td>
<td>75g</td>
<td>34.8</td>
<td>Broke</td>
</tr>
<tr>
<td>4A scratched</td>
<td>75g</td>
<td>34.8</td>
<td>Broke</td>
</tr>
</tbody>
</table>

Table 2: Visor blast testing post-trial photographs.
was a kneeling position, with both knees on the ground. A wooden rig was used to position the hips and knees into the kneeling position. The joints and neck were adjusted to give a set stiffness, and were then readjusted between shots. The positioning rig supports the mannequin in the desired position before the blast. As soon as the blast wave passes the mannequin backward, the chains go slack and the round crossbars fall from their supports, allowing free movement of the mannequin during the blast event. The measurement fixture is used to ensure that is large enough to prevent reflection of parts of the mannequin body at specific X, Y, and Z distances from ground zero. A reference pressure change was placed at 90 degrees to the blast as the mannequin’s visor surface temperature was measured using an infrared digital temperature-measurement device and the trial commenced once the surface temperature reached 15°C.

The external temperatures in January in Suffield, Alberta, Canada, average between -31 and -36°C and snowfall averages 22cm. In order to minimize temperature effects on the polycarbonate visors, they were stored in a heated building with the temperature maintained between 15 and 20°C. The visors were then transported in an insulated container to the heated tent and placed on the Hybrid III mannequin. The surface temperature was measured using an infrared digital temperature-measurement device and the trial commenced once the surface temperature reached 15°C.

Blast Test Results

The visor blast testing took place at DRDC Suffield from 15-22 January 2008. In total, 18 visors were subjected to blast testing in the enclosed, inflatable tent facility illustrated in Figure 2 on page 72. External daytime temperatures ranged from a high of 3°C to a low of -23°C, and wind speed ranged from 11 to 65 km/h. Despite these extreme weather conditions, the temperature inside the tent was maintained at approximately 15°C with the assistance of two portable, diesel generators, and wind effects were negligible. Testing began at the CEN Workshop Agreement’s recommended charge sizes of 20kg C4 (240g TNT equivalent). After failure of the visor at 200g, the charge size was decreased to 150g. In an attempt to achieve visor survival at charge sizes closer to the recommended standard, a thinner apron was added to the mannequin. However, with breaching of the visor at 100g even with the apron, it was decided to proceed without an apron and to reduce the charge size to 75g.

Table 3: V50 test results example.

<table>
<thead>
<tr>
<th>Description</th>
<th>10N-NEW</th>
<th>V50 (m/s)</th>
<th>Std Dev (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet</td>
<td>FSP-17</td>
<td>234</td>
<td>29</td>
</tr>
<tr>
<td>Shot</td>
<td>1</td>
<td>485</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>437</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>255</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>261</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>151</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>232</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>262</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>206</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>325</td>
<td>216</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>302</td>
<td>187</td>
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<tr>
<td></td>
<td>11</td>
<td>254</td>
<td>187</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>194</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>367</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>301</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>447</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>249</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>360</td>
<td>204</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>338</td>
<td>233</td>
</tr>
</tbody>
</table>

Table 4: V50 test results summary.

<table>
<thead>
<tr>
<th>Visor Condition</th>
<th>V50 (m/s)</th>
<th>Std Dev (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>234</td>
<td>29</td>
</tr>
<tr>
<td>Scratched</td>
<td>226</td>
<td>40</td>
</tr>
<tr>
<td>Scratched &amp; Heat Treated</td>
<td>247</td>
<td>18</td>
</tr>
</tbody>
</table>

Figure 3: Strike velocity (Vs) versus residual velocity (Vr).
Ballistic Test Results

The results of the ballistic tests were much more difficult to interpret. The photographs in Table 2 show the extent of damage to the visors that were broken in the trials, as well as the visors that did not break. During the trials, the pieces of broken visors were frequently transported through the target area and the pieces were photographed where they landed. All visor pieces were then collected and reconstructed for the photographs as illustrated in Table 2 (see page 73).

Discussion

The results of the ballistic testing illustrate that the threshold for visor breakage for scratched, heat-treated, and even new visors was far below the recommended charge size, when 20g C4 was used. Compared with the results of the heat-treated visors and the scratched and heat-treated visors, as noted in Table 2 (see page 73), reflects more extensive chipping of the heat-treat ed visors. The significance of this difference would require further testing, especially since all three groups of visors were found to break at less than half of the specified CEN Workshop Agreement charge size.

Observations from field experience suggest that visors subjected to detonations of up to 250g TNT do not tend to shatter as they did in these tests. Assuming these observations to be accurate, it could indicate that there was a flaw in the experiment or that the CWA op tion to use a substitute for TNT needs to be re- viewed, either the equivalence criterion needs to be changed, or perhaps no substitute for TNT should be allowed. More experimentation will be needed to answer this question.

Table 3 (see page 74) shows the V 50 test data for the new visor. The strike velocity is the velocity at which the projectile struck the face of the visor. If the projectile traveled through the visor, the strike velocity was shown as residual velocity. Residual velocity was not captured in all cases. To calculate V 50, three shots that did not penetrate and three shots that did penetrate were selected, while attempting to keep the strike velocities reasonably constant (the target was within ±40m/s).

This method prevents the far outlying data such as shot 1 from influencing the V 50 value. The V 50 ballistic tests are summarized in Table 4 (see previous page). They show that with the exception of standard deviation, all three conditions of the visors have effectively the same V 50 rating. If anything, the heat treatment may have improved the V 50 performance slightly.

Figure 3 (see previous page) presents the results of the ballistic trials that allows comparison of the three conditions. The data points are for the shots that did not penetrate or the shots in which complete penetration did not occur (residual velocity is zero), while those above the horizontal axis show those that did penetrate completely. A variety of trend lines can be drawn through the three data sets, but they are very close to overlapping. With the widespread range of velocities and relatively few data points, there is really little or no significant difference among the three curves. In other words, the results suggest that neither the scratching nor the heat treatment of the visors degraded the new visors from a V 50 ballistic standpoint.

• The proposed heat treatment of the scratched visors appears to degrade the ballistic resistance of the visors.

Amending the Ottawa Convention: A Wise Form of, Return [from page 4]


Aid Effectiveness in insecure Areas, Nausis [from page 6]

13. UNMAA’s rapid-response exercise by Hedin, Hallid, and McCall [from page 18]

1. Because the exercise is comprised of a version of what a possible realistic scenario would be, one “practice day” is in one’s time in the framework of the exercise, but less than one day in actual time.

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