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DNA'S DANDY, BUT WHAT ABOUT BODY ARMOR?

As lethal threats to police increase, protection languishes -- but there's hope

By Julius (Jay) Wachtel. It's no surprise that Boston cops feel a chill. With criminals wielding powerful semi-automatic weapons whose rounds can sail through walls (and, as in an incident last week, pierce a mattress and strike a 12-year old girl watching T.V.) you've got to wonder why anyone would be so foolhardy as to pin on a badge.

Commenting on the tragic event, Boston's commish bemoaned the proliferation of assault rifles, like the one that wounded the child. They are indeed a significant threat. But there are others. In March a parolee used an AK-type rifle to kill two Oakland SWAT officers who burst into the apartment where he was hiding. Police were there because the man had just shot and killed two patrol officers -- with an ordinary pistol.

And it's not just "real" criminals who we should worry about. Consider the middle-aged Virginia Beach man who, angry over his eviction, opened up with an AK-47 and a MAC pistol, killing two and wounding three before taking his own life. Or the recent massacre in Alabama where a deeply disturbed 28-year old went on a rampage, slaying ten and wounding six. His weapons? A handgun, a shotgun and two assault rifles.

You'd think that with all the bullets flying around there would be a massive, Federally coordinated effort to improve ballistic protection for police. But you'd be wrong. Compared to the huge bundles of cash that get thrown at DNA, what's spent on body armor R & D is puny. Firearms lethality has gone through the roof, yet what beat cops wear today -- when they can, if it's not too hot -- isn't much different in comfort and protection than what they wore *decades* ago.

Enough ranting. At the recent NIJ conference your blogger met someone who really knows what he's talking about. S. Leigh Phoenix (he goes by Leigh) is Professor of Mechanical and Aerospace Engineering at Cornell University. On faculty since 1974, Leigh specializes in composite materials and high performance fabrics. Dr. Phoenix has designed composite overwraps for containers used in the Space Shuttle and space station programs. He's also been working on ways to measure, predict and enhance the performance of police body armor. If you're half as interested in keeping cops protected as he is, read on!

An interview with S. Leigh Phoenix, Ph.D.

How does soft body armor work?

When a projectile hits it creates a small pyramid-shaped pocket. Soft armor, which is comprised of many fabric layers, tries to slow down the projectile by pushing back on it at the peak of this pyramid. The best analogy is to a tent, with the central pole representing the projectile. Applying tension to the sides of the tent drives the pole into the ground. As tension on the tent guys increases and the tent's wall angles become steeper the force on the pole also increases.

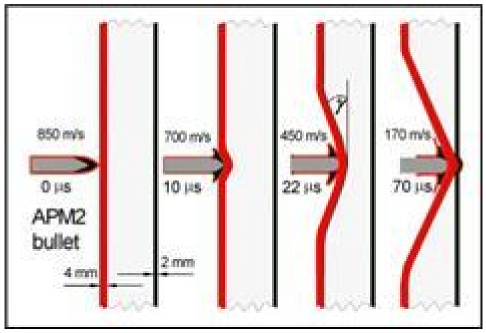
What happens when a bullet strikes armor?

When a continuous-weave fabric is struck by a bullet tension waves fan out in all directions along the yarns, traveling at more than ten times the bullet's speed. Yarn material behind the waves feeds back towards the peak of the pyramid, allowing a relatively deep pocket to form with fairly steep angles (the steeper the better.) Normally the first few fabric layers will be penetrated, which slows down the projectile a bit. It's the job of the remaining layers to bring it to a full stop.

Yarns used in body armor are more than five times lighter than steel, yet two to three times stronger. They must be very light, stiff and resistant to stretching. These characteristics allow tension waves to travel quickly; they also keep strands from breaking as they're pulled into the pyramid. Fabrics must also be light, for wearability, and sufficiently flexible to resist crushing and shattering. Some of these factors work against each other, which complicates things.

Why are ceramic plates used?

Fabric works better when the diameter of the impact patch increases. When high velocity bullets with sharp points strike a plate their tips are blunted. Continued contact with the plate causes mushrooming and deposits debris, further reducing the projectile's velocity. Current ceramic plates are completely sacrificed in the process.



Is this the ballistic vest of the future?

How can we stop high-velocity ammunition?

The diagram depicts a hypothetical approach to stopping an armor-piercing rifle round using a combination of ceramic plates and soft armor. Here the “super” ceramic plate (4 mm. layer) has some flexibility and initially blunts the projectile, causing the lead inside the tip (dark area) to splay out. As the bullet continues its copper jacket slides forward and mushrooms and the interior steel core (large pencil-like region behind the lead) tries to push through, but you want to blunt that too, which takes a little more distance. A final fabric panel brings the slowed projectile to a full stop. This concept illustrates a basic tradeoff: you need distance to stop a projectile, but you don’t want to fill the needed space with heavy materials or the vest will be too heavy to wear.

Impressive. But ceramics are hot and heavy. Are there alternatives?

With research and testing it could be possible to develop considerably lighter ceramics that can better withstand the rigors of the job

There’s another approach. At present all ballistic vest yarn is continuous, allowing material to be sent to the impact point. However, the first few layers are usually penetrated, accomplishing little other than some projectile slowing and blunting. It turns out that a single layer of unwoven yarn can be hit at much higher speed without breaking because it’s not loaded down by the drag of all the other yarns around it, especially as the pyramid deepens. In fact, a two or three inch length of the very strongest yarns can be hit at up to 2500 fps without breaking, even with a pointed-tip projectile.

I’ve given thought to using discontinuous yarns -- small segments, say two inches long -- for the first few layers, which instead of snapping would form a wad around the projectile’s nose as it plows through. That would increase the bullet’s frontal area, slowing it down and helping the fabric underneath do its job. Naturally, it would require a lot of development and experimentation to optimize fiber lengths and combinations. Calculations suggest that it could work with velocities in the 2400 fps range, which covers some rifle threats. Otherwise there will be a need for some ceramic, though maybe a lot thinner than what's now used.

Officers are dying from head shots. What about helmets?

Helmets have a couple of limitations. First, they must float a distance from the skull so there's room for deflection. They also lack wide, flat surfaces that can be covered with material to pull into the pyramid. So one can't just take ballistic vest technology and apply it to helmets. But I think that it's possible to develop a helmet that's effective against handguns and light enough to wear on patrol.

What's happened in the last twenty years to improve ballistic protection for police?

Really, not that much. Kevlar has been tweaked, yielding stiffness/strength combinations that marginally improve its velocity performance. A few new fibers have come out. Zylon, which was used on vests and seemed superior, is now on hold due to degradation concerns. Another fiber, M5, potentially much stronger than Kevlar, hasn't gone commercial because of manufacturing or other problems. Two ultra high-strength polyethylene fibers, Dyneema and Spectra, are 50 percent lighter than Kevlar and just as strong and stiff. They've been used in cockpit doors. They may still be too expensive for wide use in vests but perhaps ideal for the helmets mentioned earlier.

Private industry has a big stake in body armor. Can't we expect them to lead the way?

Body armor makers sell all they produce, so I don't see major improvements happening under the present commercially-driven system. I know of an example where extensive manufacturing changes could make yarns stronger, but the company isn't convinced that the investment would pay off financially. Manufacturers also hold their work very close to the chest. They have their own ideas, needs and priorities and collaborating with them is generally difficult, though I've been fortunate in one case.

What about Government funding?

Funds from government agencies like NSF and the Army are available if you've got the right buzzwords, meaning nanotech, biotech, carbon nanotube structures and so forth, but a lot of what gets proposed and funded is unlikely to lead to useful applications in the near term. Funding systematic work on something practical like body armor is difficult because those making the decisions (who never get shot at) consider the topic old-hat and think that the problems have been addressed and solved, which they certainly have not.

Federal law enforcement research dollars are spread very thin, especially when it comes to academic institutions. DOD concentrates on vehicle armor. Their successes are classified, making them unavailable to university researchers.

Where should we go from here?

A lot could probably be done working with present fiber materials, tweaking them with improved processing to increase their strength without changing the basic chemical structure. You could change how fabrics are designed, say, by developing hybrid layered structures. Coming up with an altogether new material could yield big improvements, but we should not underestimate what clever manipulating can do.

To push the frontiers not just as a scientific exercise but with the objective of making significant, practical improvements requires a consortium of knowledgeable, technically-adept researchers who appreciate all the issues, including the need for comfort so that body armor actually gets worn. In other words, one must work on the whole package. We need resources for research and experimentation. We also need an agency or a group of agencies that would host a long-term, comprehensive effort to develop a new materials system that would yield armor that is more protective and comfortable.

Source for figure: S. Phoenix and P. Porwal, “A new membrane model for the ballistic impact response and V50 performance of multi-ply fibrous systems,” *International Journal of Solids and Structures* (vol. 40, 2003, p. 6724)