Shear Thickening Fluid, Fabric Composites For Ballistic And Impact Protection

University of Delaware

The improvised knife was a blur in the convict's hand. It struck the prison guard squarely in the back, but the blade never penetrated, thanks to the light, flexible vest the guard wore.

The 76-year-old woman slipped on the ice and slammed to the sidewalk, but no bones were broken. A special garment helped absorb the energy of the fall and protect her fragile hip.

A football quarterback cuts through the line and avoids tacklers with astounding dexterity. His new lighter, closer-fitting helmet provides better protection than the old one but saves precious weight for greater agility on the field.

What do all these incidents have in common? All three show the potential of shear thickening fluid (STF) fabric technology, which was developed at the Center for Composite Materials at the University of Delaware (UD) and is now moving into commercial application for ballistic, impact and puncture protection.

The Origin of STF Technology

“Shear thickening fluids have a peculiar property,” says Norman J. Wagner, Ph.D., and chair of the Chemical Engineering Department at UD. “They act like a liquid at rest but thicken quickly or behave like a solid when subjected to mechanical stress. So in some ways, a shear thickening fluid behaves a bit like the clutch on your automobile seat belt. If you pull the belt slowly, you can slide it out to the length you need. But if you yank the belt quickly, it locks in place and won't move.

“These liquids have been around forever,” he adds. “The best-known example is corn starch. Drop some in warm water, stir it and — bingo! — it thickens.”

While Wagner and his students didn't invent shear thickening fluids, since the early 1990s they have been doing basic research into them. Funded by the National Science Foundation, they have been investigating colloidal suspensions — fluids with particles in them — trying to understand their basic physics and chemistry.

“Our group was one of the first to discover the science behind how and why shear thickening happens and then to be able to use that knowledge for engineering,” Wagner says. “We've looked at the problem from both sides. Sometimes — like when you're pumping a fluid that is loaded with particles — you don't want shear thickening to happen, and you look for ways to prevent it. Other times, you want shear thickening, and you want to tailor the way in which it happens.”

Body armor, for example, is an application in which shear thickening would be an advantage. The problem with conventional body armor is that, to provide protection against higher energy bullets, additional layers of ballistic fabric must be used. As the energy of the bullets rises, so does the number of layers of ballistic fabric needed to provide protection. Eventually, the ballistic vest becomes extremely thick, stiff and bulky, and people stop wearing them because they are so uncomfortable. Further, the body armor that can stop a bullet from a handgun won't necessarily be able to stop a penetrating object like an ice pick that can work its way between the threads of the ballistic fabric.

The Invention of STF Fabric

What Wagner and his team discovered was that you could take extremely finely divided silica (submicron-sized particles, with a surface area of hundreds of square meters per gram), suspend it in water or polyethylene glycol and apply it to ballistic fabric made from Kevlar or other high performance fibers, and now you have an STF fabric that instantly stiffens, by locking the fiber network, on impact. When you apply the STF treatment to the ballistic fabric, it becomes more effective. That means you can reduce the number of layers needed to provide a particular level of protection, which reduces the weight, increases the flexibility and makes the body armor more wearable.

Further, the shear force causes the suspension to lock the threads in place, so that a penetrating object, like an ice pick, can no longer get through.

Licensing the Technology

“The key UD STF-related technology that we have already licensed is an STF treatment that can be applied to many fabrics — Kevlar, nylon, polyester — to improve their performance,” says Bruce Morrissey, director of technical development in the Intellectual Property Center at UD's Office of Economic Innovation and Partnerships (OEIP).

> *Because STF fabric technology offers so many potential uses, identifying the full scope of potential products is challenging.*

“One of the most prominent features of this technology is that it can be tailored for various applications,” says Brad

Yops, assistant director of UD's Intellectual Property Center. "So we've taken a team approach to characterize the various business opportunities where Kevlar or ballistic-type fabrics, as well as traditional woven fabrics such as nylon and polyester, are used in the real world."

Ultimately, licensing will benefit not just end users, but the university and its researchers as well. "We have several motives behind our desire to license," Morrissey says. "First, the university and researchers like Norm Wagner really want to get their technology, their ideas, into the public arena for public benefit. The second is to generate a revenue stream. One-third goes to the inventors, a third to the College of Engineering and Center for Composite Materials, and a third to UD's tech transfer office to fund proof-of-concept work for other licensable technology.

"In due course," Morrissey says, "we settled on a preferred supplier — Barrday Inc. — a textile supplier based in Cambridge, Ontario, Canada, that invested in basic research related to this technology and that could supply STF-treated fabrics to just about any company that wants to produce a product based on STF technology."

Responsibility for the economic development of the STF technologies lies with the university's OEIP. "The office functions as a communication gateway that provides the outside world with access to the university's knowledge-based assets, and UD personnel and students with a window to opportunities outside the university," says OEIP Director David S. Weir.

Moving the Technology Forward

"Originally, we were partnered with the university and a third party that had licensed STF technology for ballistic defense," says Keith Butler, vice president of sales and marketing for Barrday Inc. "But when the ballistic license ended, we had already invested heavily in moving this technology from the beaker to the production line, so we decided to pursue a more broad license directly from UD."

Barrday faced and overcame significant challenges. "Three years ago, we could only make a 10-inch by 10-inch square of STF-treated material. We had to figure out how to produce it in a continuous process," he adds. "Now we can deliver the industrial quantities needed to manufacture, for example, thousands of ballistic vests. Our business model is to be partnered with the university to supply treated rolled goods to companies that want to make innovative products that incorporate STF fabric."

It's Butler's view that the marketplace is barely at the tip of the iceberg in terms of potential applications for STF fabric technology. Beyond protection for police, soldiers, prison guards and the like, there are applications in heavy industry, sporting goods, energy absorbing pads and even blast containment.

"Fortunately, we're in a position to tailor materials for specific applications and to provide advice on how to use them," Butler says. "It will be very interesting to see what the impact of STF technology will be in the next few years, whether it is protecting people and equipment or making sports safer and more pleasurable."

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