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Snopko A., Piskun O.

Liquid armor

Belarusian National Technical University
Minsk, Belarus

The term "liquid body armor" can be a little misleading. For some people, it brings to mind the idea of moving fluid sandwiched between two layers of solid material. However, both types of liquid armor in development work without a visible liquid layer. Instead, they use Kevlar that has been soaked in one of two fluids. The first is a shear-thickening fluid (STF), which behaves like a solid when it encounters mechanical stress or shear. In other words, it moves like a liquid until an object strikes or agitates it forcefully. Then, it hardens in a few milliseconds. This is the opposite of a shear-thinning fluid, like paint, which becomes thinner when it is agitated or shaken. You can see what shear-thickening fluid looks like by examining a solution of nearly equal parts of cornstarch and water. If you stir it slowly, the substance moves like a liquid. But if you hit it, its surface abruptly solidifies. You can also shape it into a ball, but when you stop applying pressure, the ball falls apart [1].

Here's how the process works. The fluid is a colloid, made of tiny particles suspended in a liquid. The particles repel each other slightly, so they float easily throughout the liquid without clumping together or settling to the bottom. But the energy of a sudden impact overwhelms the repulsive forces between the particles -- they stick together, forming masses called hydro clusters. When the energy from the impact dissipates, the particles begin to repel one another again. The hydro clusters fall apart, and the apparently solid substance reverts to a liquid.

The fluid used in body armor is made of silica particles suspended in polyethylene glycol. Silica is a component of sand and quartz, and polyethylene glycol is a polymer commonly used in laxatives and lubricants. The silica particles are only a few nanometers in diameter; so many reports describe this fluid as a form of nanotechnology [2].

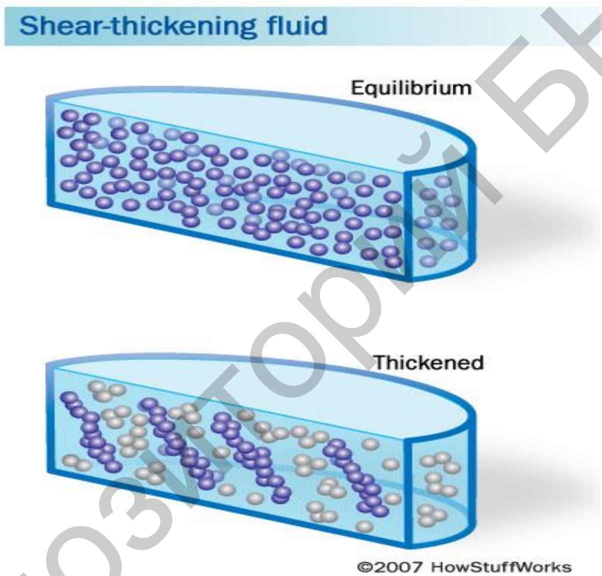

Fig.1-Before impact, the particles in shear-thickening fluid are in a state of equilibrium. - After impact, they clump together, forming solid structures.

To make liquid body armor using shear-thickening fluid, researchers first dilute the fluid in ethanol. They saturate the Kevlar with the diluted fluid and place it in an oven to evaporate the ethanol. The STF then permeates the Kevlar, and the Kevlar strands hold the particle-filled fluid in place. When an object strikes or stabs the Kevlar, the fluid immediately hardens, making the Kevlar stronger. The hardening process happens in mere milliseconds, and the armor becomes flexible again afterward. In laboratory tests, STF-treated Kevlar is as flexible as plain, or neat, Kevlar. The difference is that it's stronger, so armor using STF requires fewer layers of material. Four layers of STF-treated Kevlar can dissipate the same amount of energy as 14 layers of neat Kevlar. In addition, STF-treated fibers don't stretch as far on impact as ordinary fibers, meaning that bullets don't penetrate as deeply into the armor or a person's tissue underneath [3]. The researchers theorize that this is because it takes more energy for the bullet to stretch the STF-treated fibers. Research on STF-based liquid body armor is ongoing at the U.S. Army Research Laboratory and the University of Delaware. Researchers at MIT, on the other hand, are examining a different fluid for use in body armor. We'll look at their research in our further research.

References:

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