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Issue 45

In This Issue

Full Fluid Jacket – Liquid Body Armor

Photo courtesy of US Army, taken by Specialist Kirby Rider

Humans have waged war on one another for centuries. Weapons have evolved from sticks and stones through cutting and bludgeoning implements to today's smart bombs and missiles. But the evolution of the means to protect oneself from the impact of those weapons has not kept pace. However, a new technology combining two advanced materials – Kevlar and shear-thickening fluid – may hold the promise of light, flexible and effective full body armor.

Today's body armor is a compromise between protection and agility. Most modern body armor comprises many layers of woven Kevlar, sometimes with ceramic plates to give extra protection. Kevlar is an aramidic fiber, which forms hydrogen bonds between its chains of molecules and thus has a very high tensile strength and high toughness. It is five times stronger than steel on an equal weight basis and it already saves countless lives.

Although Kevlar offers vastly increased protection for the wearer, it does have some drawbacks. For effective protection, up to 30 or 40 layers of Kevlar are needed. This many layers, together with additional ceramic plates, make the armor bulky, stiff and heavy, meaning that the wearer cannot move around as easily. Also, body armor does not offer protection for extremities, such as arms, legs or the neck because the number of layers of Kevlar needed to offer sufficient protection would be too stiff and bulky for use as sleeves, trousers, and so on.

A great deal of largely US-military-funded research has taken place over the last few years into combining Kevlar fabric with a shear-thickening fluid. Shear-thickening fluid is an example of a "smart material," a class of materials that can sense and respond to changes in the environment, for example through the application of electricity or magnetism, or to changes in temperature. Shear-thickening fluids increase their viscosity in response to changes in pressure. An example of a fluid under research is ethylene glycol containing suspended nano-particles of silica. Under normal conditions, the particles are weakly bonded to each other and can move around with ease. The shock of an impact strengthens those chemical bonds and the particles lock into place. Once the force from the impact dissipates, the bonds weaken again.

The liquid technology can improve both the performance and the utility of Kevlar fabric. Saturating Kevlar fabric in a shear-thickening fluid causes the fluid molecules that are already bonded with each other to also form weak chemical bonds with the polymer chains of the Kevlar fibers. The weak bonding allows the fabric to remain flexible. When a projectile strikes the fabric, it becomes rigid within two-thousandths of a second, preventing penetration. Furthermore, the reduced flow of the fluids in the liquid armor restricts the motion of the fabric yarns in relation to each other, resulting in an increase in the area over which the impact energy is dispersed. As a result, the material does not distort as much as the standard body armor, which generally extends inwards substantially when a projectile strikes, causing considerable pain and injury. Once the event is over, the fabric returns to its former flexible state.

The mechanical properties of the material are being evaluated using a wide range of tests and test equipment. Drop towers test puncture resistance with knives and icepicks as well as various shapes and sizes of instrumented tups. Load frames are used to test resistance to abrasion, fiber pullout, and tearing. Gas guns are used to fire ballistics such as bullets and shrapnel.

Impregnating Kevlar with a shear-thickening fluid strengthens the fabric to such an extent that improved protection can be achieved with a material that is one-third the thickness of Kevlar alone. Therefore the body armor can be lighter, more flexible and yet offer greater protection from projectiles, shrapnel and explosive devices – the major causes of injury and death in modern conflicts. Seventy per cent of all non-fatal injuries and sixteen per cent of deaths in a war zone are due to trauma to extremities. Because fewer layers are necessary with the new material, supple armor for arms and legs is now possible.

Extremity armor using shear-thickening fluid impregnated Kevlar could significantly reduce the number of injuries in battle as well as saving lives.

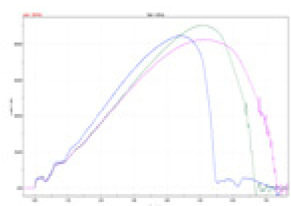
Don’t Let a Blemished Tup Impact Your Results

When performing impact tests with any system, the condition of the striker or tup strongly influences the validity of the data collected. Blemishes such as nicks, gouges, deformation or other damage to the tup can change the data being collected. Nicks and deep gouges on the tup surface cause friction and drag as the tup passes through the specimen. Repeated use of the tup can result in flattening on the tip creating a larger surface area. This deformation changes the loads produced as well as the duration of the impact event.

The following images show deformation of a tup insert over time and the variations in data captured by these tups on the same tester, material, material dimensions, and test conditions. So, to keep your data accurate and consistent, remember to examine your tup inserts regularly and replace them whenever you discover deformation or damage.

Q. When looking at my instrumented impact test data, which result should I focus on more – peak load, energy at peak load, or time to peak load?

A. While all these results provide insight into how a material behaves under impact loads, the value or values that you should focus on should consider the end use of the material.



For example, if the material is going to become a containment vessel such as a bottle or a syringe, you may want to focus not on the maximum values but on areas of the curve that indicate the occurrence of incipient crack damage. Focusing on these areas lets you judge at what energies and time into the test when the damage starts. This insight lets you concentrate on improving the material itself or the product design to increase its strength.

If the primary function of the end product produced is to absorb or remove a large amount of energy, you may want to focus more on the values of energy at peak load and total energy as well as examining how long it took to reach those values. Paying attention to these results provides you with insight as to how well the specimen under test is performing its primary function – protecting the contents by removing or redistributing the impact energy.

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