How Silicon-based Technology Provides "Intelligent" Impact Protection to Textiles

By: Graham Budden and Fernando Vazquez – Dow Corning Corporation

Introduction

One of the largest growth areas in the textile market is the development of "smart" technical textiles that provide added functionality for the user. Much research has focused on fabrics that automatically adjust to changes in body temperature or humidity to deliver improved breathability and comfort for the wearer. Other fabrics provide UV protection or abrasion resistance. Some are treated to be super absorbent or anti-microbial. But until now, impact protection has largely remained the domain of hard armor systems.

A new and innovative silicon-based technology developed by Dow Corning Corporation – the *Dow Corning*® Active Protection System – provides the solution to a problem that has long challenged textile manufacturers: Is it possible to develop a fabric that effectively protects against high-energy impacts without sacrificing flexibility, breathability, and ease of use? And just as importantly, could this fabric provide a level of design and fabrication versatility that would make it suitable for integration into existing garment manufacturing processes?

With the recent introduction of *Dow Corning* Active Protection System fabric, the answer to both questions is a resounding "yes."

Overview of the technology

Dow Corning first developed this technology to meet the needs of the high-performance sports apparel market – specifically, the motorcycle industry – with two key objectives:

1) Provide superior protection against high-energy, blunt-force impact.
2) Deliver this protection with maximum comfort for the wearer.

To meet this challenge, Dow Corning made use of the characteristics of a special type of silicone impregnated into a carrier textile. The result is a patented technology for the creation of impact protection textiles that offer superior defense against high-impact force. These fabrics are fully flexible and breathable and, additionally, mold to the body form.

Figure 1. Dow Corning *Active Protection System fabric used in motorcycle riding suit*

The technology consists of a three-dimensional spacer textile support coated with soft, malleable, and formable silicone material. The extent of the impregnation is controlled so that the fabric remains both fully breathable

for maximum comfort and easily bendable to allow conformity to the body. It remains soft and flexible under normal conditions, but when stressed under a high-impact force, it instantly transforms to a rigid solid, but only for the duration of the impacting force. After the force has been dissipated through the fabric construction, the silicone quickly becomes soft and flexible again.

The choice of textile affects overall impact performance and comfort. Spacer fabrics have been shown to be particularly advantageous and can enhance impact performance, flexibility, and comfort. Key parameters for these three-dimensional structures include thickness, monofilament density, monofilament thickness, and angle of the monofilament surface configuration.

When impregnating the fabric, it is particularly important to present the silicone so that it can readily absorb the impacting force through the spacer yarns in the direction of the force. Careful engineering of the dimensions of the spacer textile ensures this orientation, allowing the silicone to absorb maximum force, yet leaving the fabric completely breathable.

The silicone on the fabric surface and the spacer yarns in the immediate strike area first receive the impacting force. These instantly become rigid and transmit energy to adjacent spacer yarns, which also become rigid, thus spreading the impact. See Figure 2.

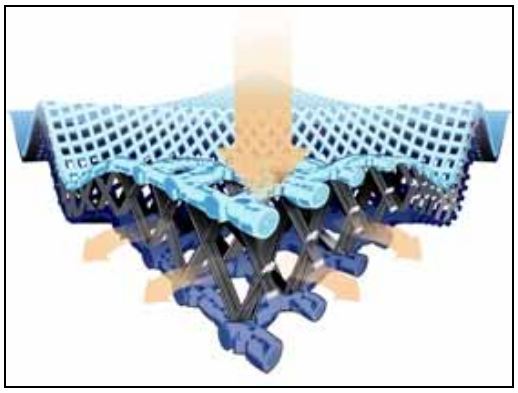

Figure 2. Cross section of impact protection fabric

Key features and benefits

When used in personal impact protection systems, this fabric offers a unique combination of performance and comfort benefits that are particularly suited for use in protective clothing and equipment:

- High Performance: Instantly absorbs and dissipates high-impact energy.
- Flexible: Delivers unrestricted freedom of movement.
- Breathable: Uses an open structure that allows natural ventilation and airflow.
- Versatile: Can be cut, shaped, and contoured for virtually unlimited design possibilities.
- Customizable: Material properties can be adapted to meet exact manufacturer needs.

Because its protective capabilities are silicon-based, the fabric is also thermally stable. A slight tack develops at temperatures over about 80˚C, but disappears upon cooling. The fabric remains flexible at low temperatures (-20˚C) and is not expected to experience any adverse effects in regard to flexibility or impact performance, even at temperatures as low as -40˚C.

Test results

Independent testing shows that the Active Protection System meets or exceeds EU protection standards for a variety of sports apparel and equipment. In these tests, a weight is dropped vertically onto the test piece and the transmitted force is measured. For example, the graph in Figure 3 shows a typical impact event under EN 1621-1 test conditions for limb protection in motorcycle apparel. This test, in which transmitted force is plotted over time, compares a typical hard-shell protector with Active Protection System fabric.

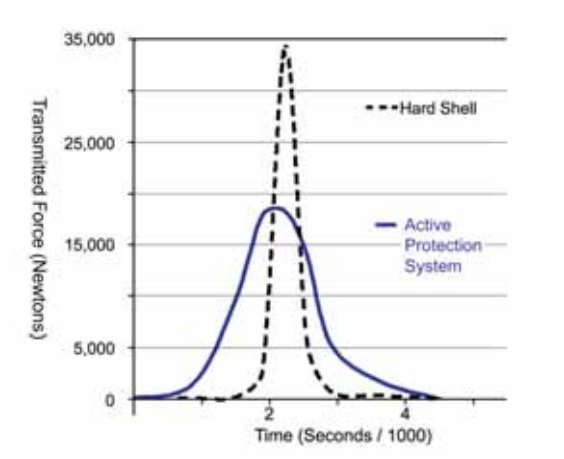

Figure 3. Typical impact results

Of particular note in this example are the lower peak force and duration of the peak force displayed by the fabric. The textile dissipates the impact energy over a longer period than hard armor, which results in a less traumatic impact event. By contrast, a typical hard-armor product shows a higher force response over a shorter time. For the wearer, this means the force is felt more and could lead to more soft tissue damage.

By using the fabric in several layers, it is possible to protect very specific areas against varying impact levels. For example, two layers can be used on elbows, shoulders, and knees, three to four layers on the spine for maximum protection, and perhaps one layer along the forearm or shin. Results can also vary depending on the weight of silicone impregnated into the textile.

Further testing has been completed using the EN 1621-1 standard to assess performance against higher impact energies and the effect of multiple layers of fabric. Results are shown in Figure 4. Of particular interest is the large drop in transmitted force achieved by layering the fabric. This is due to the increased thickness along with a smaller contribution from the discontinuity between the fabric layers, which also helps reduce the transmitted force.

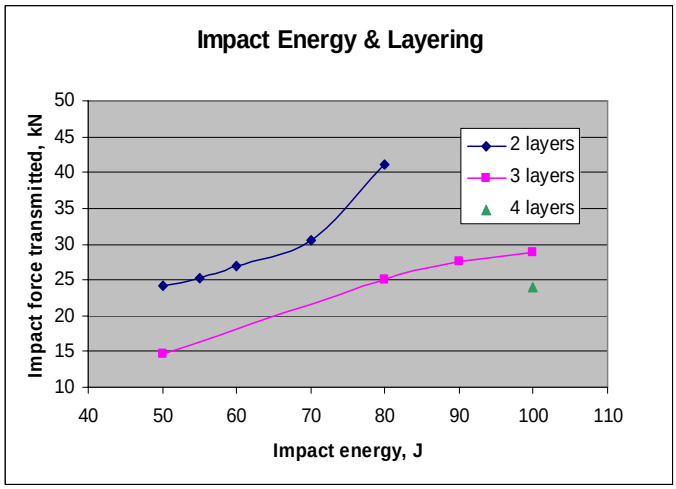

Figure 4. Impact results at higher energies

In addition to the EN 1621 standards for motorcycle apparel, Dow Corning has begun initial testing of Active Protection System fabric against European Standards minimum safety requirements for a selection of other sports-related protective devices including:

- Equestrian Shoulder Protectors
- Martial Arts Head Guards
- Soccer Shin Guards
- Field Hockey Shin Guards
- Cricket Thigh Guards
- Cricket Batsmen Gloves
- Ski Helmets

The results show that the protective fabric is capable of passing all the standards when suitably layered to increase thickness. In many cases, the thickness is less than current armor, plus it has the advantage of much improved flexibility and breathability.

Because the fabric is porous and breathable it is not "waterproof" in that it does not provide barrier protection against water. However, testing on motorcycle apparel

shows that the fabric does not lose performance when wet, which is very important for many applications.

Obviously, the technology has not yet been tested for every possible application condition. Like any new technology, it is incumbent upon the end-product manufacturer to determine its own guidelines based on an item's intended use, specific requirements, and testing conditions.

Application opportunities

The high level of comfort and impact performance combined with the versatility of having a textile solution rather than a component molded part offers virtually unlimited application opportunities that extend far beyond the apparel market:

- Industrial and geo fabrics: compartment lining fabrics, protective casings and enclosures, sound damping
- Medical devices: hip protection, head protection, orthopedic accessories
- Architecture and construction: energy-absorbent flooring, blast protection, sound damping
- Military and civil defense: concealable armor, fragment armor, blast protection, helmets

Apparel and equipment designers can use Active Protection System fabric in places where hard armor would be too bulky, inflexible, or unwieldy. It also integrates easily into existing manufacturing processes because it can be cut and sewn. (Heat welding in not recommended at this time.)

In short, the *Dow Corning* Active Protection System has the potential to truly revolutionize the technical textile and impact protection market.

Source: All testing data is original and comes from Dow Corning or independent testing labs. Testing was completed according to British Standards guidelines using EN testing methods.

Dow Corning Author Biographies and Contact Information

Graham Budden

Graham Budden has a degree in chemistry from the University of Bristol (UK) as well as research experience at the University of Cambridge (UK). He has broad experience in the use of silicones for the textile industry. For the past 10 years, he has worked on applications of silicone coatings in industrial textiles, in particular those used in automotive airbags. More recently he has extended his experience to the application of silicone materials to prevent personal injury from impact events.

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Fernando Vazquez

Fernando Vazquez is a global technical leader for Dow Corning fabric finishing and a senior applications engineer for textiles in North America. He received a bachelor of science degree in chemical engineering from the National University of Mexico in Mexico City and a master of business administration from Wake Forest University in Winston-Salem, N.C., USA.

Vazquez has published several whitepapers including, "The Easy Care vs. Softness Challenge," Textile Technology International, 2005; "Trouble Free Performance in Finishing Conditions," Textile Technology International, 2004; and "Silicones: Beyond Softening in Garment Finishing" at AATCC Garment Symposium, 1999. He has been a member of the AATCC since 1999.

Superior Defense and Comfort for High-Performance Apparel and Accessories

NEW *Dow Corning*® Active Protection System

Key features and benefits

The Active Protection System offers features and benefits that other armor systems simply cannot achieve.

- ***High Impact Performance***

  The System absorbs and dissipates energy, greatly reducing impact forces transmitted to the body.

- ***Flexible***

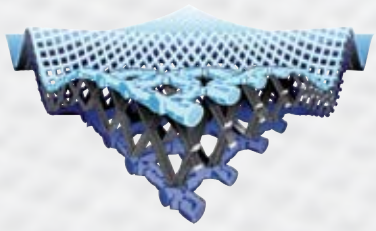
  The System is totally flexible. It readily molds to the contours of the body giving the wearer great freedom of movement.

- ***Breathable***

  The System is based on an open structure, allowing natural ventilation and airflow around the body for ultimate comfort.

- ***Customizable***

  Because the System is a textile, it can be cut into different shapes and sizes. Now you can create unique and stylish designs with protection fully integrated into the garment wherever you want it. Layers can be built up to maximize protection for vulnerable parts of the body.



Cross section of APS fabric.

What is the *Dow Corning*® Active Protection System?

The *Dow Corning*® Active Protection System is a premium "intelligent" textile that uses patented technology to deliver unprecedented levels of impact safety ***and*** comfort for the wearer. It is comprised of innovative materials that instantly become rigid upon impact, but flex with body movements when protection is not required.

Unlike bulky hard-armor component systems, the Active Protection System can be sewn directly into garments and accessories to shield the wearer against high-energy impacts. And because it is a versatile, sewable fabric, it will integrate easily and quickly into standard manufacturing processes. With the Active Protection System, you can now offer your customers a truly revolutionary advancement in protective apparel that provides:

>> Superior protection
>> Outstanding comfort
>> Freedom of movement

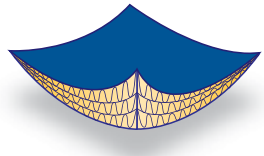
How does it work?

The patented System consists of a three-dimensional spacer textile treated with a specially formulated, responsive silicone coating. Material application is carefully controlled so the fabric retains good breathability and flexibility.

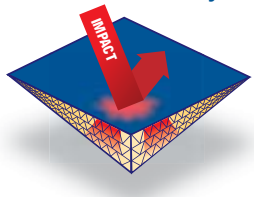
This "intelligent" textile remains soft and flexible under normal conditions, but hardens instantly upon impact. When the impact force is removed, the material immediately returns to a flexible state.

Upon impact, the Active Protection System instantly **absorbs and distributes** energy away from the impact area.

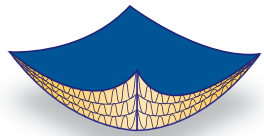
Normal conditions: Flexible



During impact: Hardens instantly



After impact: Immediately returns to a flexible state



SUPERIOR DEFENSE AND COMFORT

DOW CORNING®
ACTIVE PROTECTION SYSTEM

Independently tested, proven technology

Independent testing by a UKAS accredited laboratory proves the Active Protection System **protects earlier, lasts longer and reduces impact force significantly better than typical hard armor systems**.

Typical properties

Property	Value
Thickness*	4.8 mm
Width	1300 mm
Weight*	2.2 kgm^{-2}
Color	Dark grey – black
Maximum Peak Force**	< 28 kN

*one layer
**two layers, EN 1621-1:1997

How is it used?

APS is excellent for use in any activity in which the wearer would benefit from superior impact protection, breathability, flexibility and light weight:

>> Bicycling, motor sports, running, etc.

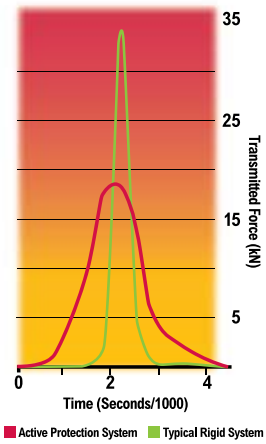
>> Contact sports like soccer, rugby, football and hockey

>> Civil and military defense

The Active Protection System is available on rolls with a release liner. The fabric can be cut into any desired shape, then built up in layers and sewn directly into the garment.

Possible cutting techniques include die cutting, scissors and laser cutting. Recommended sewing techniques include piping the edges and over-lock stitching. Putting the material on the outside of the garment is not advised.

You can easily and quickly build prototypes in-house for testing and trials. There is no need to maintain stocks of components in multiple sizes and configurations.



This diagram shows the results of a performance evaluation on two layers of APS fabric under EN 1621-1:1997 conditions. The test measures the amount of force that passes through a protective system to the body of the wearer: **the higher the peak, the lower the protection**. The maximum transmitted force allowed by this EN standard is 35 kN.

Commercially available products

***Dow Corning*® Active Protection System D1580** is our first commercially available product with several new products to be launched soon.

The Active Protection System is a very broad and versatile technology with a virtually unlimited number of potential product offerings. If the commercially available systems do not meet your exact needs, then talk to us about customization.

Promotional assistance

Dow Corning offers the benefits of its globally recognized brand to help promote your products. Use of an approved Active Protection System hangtag is required on all garments and accessories that incorporate the Active Protection System. Please contact us to discuss in more detail.

Contact us

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