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High-tech fabrics

Material benefits

High-tech fabrics: Advances in seemingly mundane textile technologies promise to make the world a safer place—using a variety of tricks

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ON APRIL 29th a Boeing 747 cargo jet crashed just after take-off at Bagram airbase in Afghanistan, killing all seven crew members. During the ascent, it seems, some heavy cargo broke free from its constraints and slid backwards, lifting the nose of the aircraft and making it stall. Such accidents have happened before. In 1997 a cargo plane leaving Miami crashed after pallets of denim shifted; all four of the crew and a motorist on the ground were killed. Accordingly, there is much interest in brawnier nets that can ensure air cargo stays put. Japan's Nippon Cargo Airlines, TAP Portugal, and, as of this summer, Air France-KLM are using netting fabric that is much stronger than the polyester netting in wide use today.

The fabric in question is woven from fibres of ultra-high-molecular-weight polyethylene (UHMWPE), a type of plastic made up of unusually long and heavy hydrocarbon chains. Such fibres have a strength-to-weight ratio around 15 times greater than steel, says Joe Ashton of AmSafe Bridport, a British manufacturer of cargo nets. The firm's nets are made of Dyneema, a UHMWPE fibre made by Royal DSM, a Dutch manufacturer, and sell for around $400 each. That is about four times as much as a typical polyester net. But as well as being much stronger, nets made with Dyneema last longer and, at about 9kg, weigh half as much, saving fuel and reducing carbon-dioxide emissions.

This is just one example of how new materials and techniques are making possible high-tech fabrics with a range of useful new properties. Humans have been weaving fabrics since the dawn of civilisation, but researchers around the world are now cooking up myriad new textiles capable of containing explosions, protecting astronauts, thwarting bacteria and even keeping buildings standing during earthquakes. These new fabrics are also finding more commonplace uses, such as helping to keep people cool in the heat or ensuring that clothes stay clean and smell fresh.

Underlying these novel materials are some unusual manufacturing techniques. Kuraray, a Japanese firm, has for example developed a clever way to harness an attribute of some polymers known as liquid crystallinity. As the name suggests, the molecules in liquid-crystal polymers (LCP) have arranged themselves to form crystals, which makes them stronger than polymers with randomly ordered molecules. Kuraray pumps melted LCP goo, heated to 300°C, through a showerhead-like device with holes 23 microns (millionths of a metre) in diameter. The resulting fibres are amazingly strong: twist together 100,000 of them to produce a cord a bit thicker than a pencil, and it can suspend about eight tonnes, or the weight of four SUVs.

Vectran, as this material is branded, is also notable for its low “creep”, or reluctance to stretch. It helps keep robots’ gestures precise when used in their cabling, for instance, and is woven into other materials to make stronger tapes, sails and slash-resistant butcher’s gloves. Lindstrand Technologies, a British maker of airships, recently switched from polyester to a Vectran-based fabric, even though it costs about ten times as much. It has the advantage of being both lighter and tougher, and can deflect small-arms fire at about 200 metres, says Per Lindstrand, the firm’s managing director.

The same material was also used in the airbags that cushion the landing of rovers sent to Mars by NASA, America’s space agency. This provided “really good PR, not so great volume”, jokes Forrest Sloan of Kuraray’s American arm. More recently, Vectran has been protecting British armoured vehicles from Russian-made rocket-propelled grenades, which use an explosion to propel a spike of copper through as much as 25cm of steel. A Vectran netting system, mounted on a light metal frame and wrapped around vehicles about 30cm from their surface, deforms the warhead tip in a way that prevents the spike from forming, says Steve Lawton of AmSafe Bridport, which designed the system.

Weave your spell

Fabrics can be given new properties by clever arrangement of their yarns. Stacking several layers of unidirectional yarns at cross angles, for example, makes a powerful “multi-axial” fabric. Using glass- and plastic-fibre yarns woven in this way, an Italian company, Selcom, has made “seismic wallpaper”. Called SENTEX 8300, it has been wrapped around a building near Venice to prevent it from collapsing during earthquakes. As well as providing support, the fabric contains embedded sensors that can be used to monitor a building’s movements during and after seismic shocks.

Another arrangement trick involves the combination of fibres to create “auxetic” yarn that, when stretched, becomes thicker rather than thinner. To understand how this works, imagine a rubber bungee cord with a piece of fishing line wrapped around its length in an open spiral. If you pull the fishing line tight, it straightens, and the bungee cord is distorted into a spiral around it—a spiral wider than the undistorted cord. Similarly, fabrics made of auxetic yarn get thicker when stretched.

This unusual property gives an auxetic textile made by Advanced Fabric Technologies (AFT), a firm based in Houston, the strength to contain powerful explosions. The textile, branded Xtegra, is made with synthetic fibres including DuPont's Kevlar and Hytrel, a rubbery plastic. Fragments of shrapnel from an explosion bounce off the fabric as it stretches and thickens to absorb their kinetic energy and then snaps back.

In a test carried out by the British Ministry of Defence, five 1mm layers of Xtegra stopped shrapnel from a rocket-propelled grenade detonated five metres away. Adjusting the size and weaving patterns of the auxetic fibre can produce materials optimised for particular uses, says David O'Keefe of AFT. His firm's customers are using Xtegra to provide protection from mine explosions, shrapnel in tank crew compartments, the rupture of oil-drilling manifolds and lashing from hurricanes.

A European consortium of nine partners including Meridiana, an Italian airline, is developing an auxetic textile capable of containing a blast in an airliner's luggage hold. The Fly-Bag project, funded by the European Union, has created multi-layered, auxetic-fabric bags that hold more than 30 pieces of luggage. In tests at Blastech, a facility near Buxton in England, a prototype successfully contained five detonations of RDX, a plastic explosive. Jim Warren, Blastech's boss, says a Fly-Bag would have contained the baggage-hold blast that tore through a Boeing 747's fuselage in 1988 over Lockerbie in Scotland, killing 270 people. The bag also smothers post-blast fires thanks to its zip-up seal and a coating that restricts airflow.

Novel materials can also protect people more directly from fire. Chapman Innovations, a firm based in Salt Lake City, makes fire-resistant garments by baking fibres made of acrylic, a form of artificial silk, at half a degree below its combustion temperature. This blackens the acrylic and cooks off its nitrogen, an element that would otherwise enable it to burn. Fabric made from the fibres, called CarbonX, is used to make garments for factory workers, firefighters, racing drivers, soldiers and police SWAT teams.

An uncommon thread

A carefully designed fabric can even prevent a fire in the first place. If static electricity collects in clothing, it can generate a spark that ignites fumes. To avoid sparking, the Barnet Trading Company in Shanghai designed a yarn made of carbon sheathed in polyester. The trick, says Ma Wei, the firm's boss, was to give the carbon core a trilobal shape. Static electricity slips off the core's three ridges, dissipating before enough accumulates to create a spark. The yarn, named Nega-Stat, is widely used in petrochemical facilities, industrial clean rooms and medical operating theatres.

Earlier this year patients at Pirogov Hospital in Sofia, Bulgaria, began receiving pyjamas and bedding made from a novel form of cotton. Its fibres had been impregnated with nanoparticles of zinc oxide, giving the material antibacterial properties. Aneta Hubenova, head of hospital's toxicology clinic, says preliminary results indicate that the patients suffered fewer infections than those in control groups.

Embedding the zinc oxide in the cotton was not easy. Researchers at the Bar-Ilan University Institute for Nanotechnology and Advanced Materials in Ramat Gan, Israel, used ultrasound to create momentary voids about ten microns in diameter in a watery solution containing zinc. As they collapse, the voids heat up and shoot tiny particles of zinc oxide into nearby cotton fibres, says Aharon Gedanken, the project leader. The EU is providing €8.3m ($11m) in funding for the project in the hope of reducing the 10m days patients spend in European hospitals annually due to infections caught within their walls.

Enhanced textiles can also be put to more everyday uses. Anti-microbial textiles reduce body odour and its attendant textile discolouration. Mosquito-repellent clothing is made by treating fabric with permethrin, a synthetic insecticide, or pyrethroid, a compound similar to a natural chrysanthemum insecticide. Water-repellent or "hydrophobic" textiles designed to prevent hyperthermia among Swiss and German soldiers are being used to make sportswear that is more comfortable in hot weather, says René Rossi of the Swiss Federal Laboratories for Materials Science and Technology, which devised the material.

At the other end of the spectrum materials are being developed to protect astronauts from dangerous radiation. High radiation levels beyond low-earth orbit mean that existing shielding materials used in spacecraft and spacesuits are inadequate for manned missions lasting more than 100 days, says Sheila Thibeault of NASA's Langley Research Centre. Her team is developing new fabrics based on tiny crystalline fibres made of boron and nitrogen, which are heated under pressure to form boron-nitride nanotubes (BNNTs). Resembling white candyfloss, these can be spun into a "pretty spectacular" yarn that stops many harmful particles, she says.

But it is still not quite good enough. The next step is to integrate hydrogen into the tubular structure of BNNTs. Modelling has shown that such hydrogenated BNNTs would provide effective shielding against the radiation encountered in interplanetary space. Dr Thibeault says her team has made good progress incorporating hydrogen in recent months. When she suggests that mankind's future in space depends on the development of new fabrics, she is not just spinning a good yarn.

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