Cracking future for fabric that heals its own breaks

Ian Sample looks at how self-healing materials inspired by nature could make cars, and space travel, safer

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Flick through the newspapers on a day of your choice and you'll find that somewhere in the world, disaster has struck because something broke when it shouldn't have. The problem is simple: no amount of testing can guarantee precisely when an engine will seize, a wing will crack, or a railway track will fracture.

Our life-and-death reliance on materials has spurred a small group of researchers into action and what they have come up with is remarkable. Instead of wood that splinters, glass that shatters and metals that crack, they have created a new generation of materials that can recover from all but the worst abuse. Crack them, and they repair themselves; break them in two, and they can be rejoined; puncture them and they bleed and heal.

The prime driver for "self-healing" materials is safety. Provided that they can repair themselves quickly enough, the new materials should shrug off damage that might otherwise spell disaster. "As soon as it is damaged, you want it to heal," says Scott White at the University of Illinois, Urbana.

The materials have other advantages. Manufacturing costs are dominated by the need to make high-performance materials as defect-free as possible. With self-healing materials, those standards could be relaxed. Any imperfections in the material will simply heal themselves.

At Princeton University in New Jersey, Dudley Saville and Ilhan Aksay are developing self-healing materials for the space industry. They are concentrating on lightweight struts to build new structures in orbit. The struts are essentially thin metal tubes, which are modified so their inner surfaces are coated with an insulator. The tubes are then filled with a solution of ions containing millions of tiny silica particles, each measuring just a micron across. Finally, a copper wire is strung down the middle of each tube, and connected via a battery to the outside of the strut.

Take one of the metal struts and bend it until it cracks and immediately, the insulating film inside the tube ruptures, exposing the bare metal beneath. This instantly sets up an electric field between the wire and the cracked metal that makes the liquid inside flow, carrying the silica particles to the damage site. Once there, the particles fill in the crack, much like a blood clot heals a wound.

"You see the crack site fill up with particles within seconds," says Aksay. A little longer, and copper ions from the electrified wire dissolve and begin to stick onto the particles, effectively cementing them in place. "It's like room temperature welding," he says.

The Princeton team have yet to see how strong their tubes are after healing, but even if the results are good, they have another hurdle to surmount. Most materials fail because of cracks starting on the outside and working inwards - so detecting cracks only once they have penetrated their struts might be far too late.

At the Exotic Materials Institute at the University of California, Los Angeles, scientists are taking a very different approach to self-healing materials. Developed by Fred Wudl and Xiangxu Chen, "Automend" is a clear, glass-like plastic that can be broken and joined back together as many times as you like. The secret to the material's healing ability is the so-called Diels-Alder reversible reaction. At room temperature, the plastic is rigid, thanks to strong bonds between two different chemical groups that hang off each molecule in the polymer. Warm the plastic up a little, and the bonds break. Cool it down, and they reform.

To fix a broken sheet of Automend, just align the fragments and hold them in place, as if you were supergluing a fumbled mug. Heating the pieces to 100C makes the fragments expand, closing up the gaps between them. At the same time, the Diels-Alder bonds break. As the plastic cools down, new chemical bonds form where the gaps used to be, making the broken sheet one piece again.

In tests, Chen found that cracked sheets of the plastic regained 83% of their strength on healing, while a sheet snapped completely in half regained 57% of its original strength.

Although Chen's material is unique in its ability to heal complete fractures, it needs to be heated to do so. It is also expensive, so self-repairing crockery is not on the horizon yet. "If we sold a self-healing bowl for £1,000, are you going to buy one? In your whole life, you're not going to use £1,000 worth of bowls," he says.

Perhaps the most advanced self-healing material is being developed by Scott White. His material mimics the biological analogy of healing more than any other. Throughout his material is a complex network of channels that form a rudimentary circulation system. Coursing through the material's "veins" is a liquid that contains a chemical healing agent, dicyclopentadiene (DCPD). When the material is cracked or punctured, the liquid in the veins leaks into the wound where it immediately comes into contact with a catalyst that makes it solidify, patching up the damage. White is tight-lipped about how well the material works. "All I can say right now is that is has great potential," he says.

Needless to say, the armed forces are keeping a close eye on self-healing materials. If they are strong and light enough, they could be used to protect military aircraft, including helicopters that are often sitting ducks for forces on the ground. Likewise, troop transporters and tanks would benefit if they could repair damage suffered on the battlefield and limp home.

The civilian transport industry sees benefits too: self-healing materials could be used to prevent unnoticed cracks and other damage spreading unseen through airliner structures or the engine components of road vehicles. "They could heal themselves before you've even realised they were damaged," says White.

The US space agency, Nasa, is also interested, as self-healing materials could help them overcome a delicate problem. Often, engineers on the ground cannot tell if a space probe is damaged after it has been launched, and even if they can, there may be little that can be done about it. You can't, after all, send a maintenance engineer to fix a broken spacecraft that is hurtling off to another planet.

While not slavishly following nature's solutions to wear and tear, scientists are convinced that materials inspired by biology have a vital role to play in the future. And materials that can heal themselves are not the only goal. White for one believes that materials with a built-in circulation system could be exploited in other ways; for cooling and heating different parts of a structure, for example, much as the body regulates its own temperature. "Humans and other biological systems have gone through eons of evolution to end up with these mechanisms and they work beautifully," he says. "We can learn a lot from them."