Media release

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Self-healing membranes

Nature shows the way

Lianas whose stabilization rings of woody cells heal spontaneously after suffering damage serve as a natural example to bionic experts of self-repairing membranes. Such membranes could find use, for example, in rubber dinghies. Empa researchers have borrowed this trick from nature and developed a polymer foam surface coating with a closed cell construction which not only reduces the pressure loss after the membrane is damaged but also makes the inflatable structure more resistant and giving it a longer operational life. The scientists report on this work in the current issue of the Journal of Bionic Engineering.

A hole in an inflatable boat is only a disaster if the air escapes too quickly to reach the safety of land. It's somewhat less dramatic but nonetheless uncomfortable to spend the night on a leaky air mattress. Even in this case, though, you can get some uninterrupted sleep if only the air leaks out slowly enough. In future, self-repairing layers of porous material should ensure that the membranes of inflatable objects are not only water and airtight but also that they can plug up any holes on their own, at least temporarily.

The idea behind this comes from nature. Bionics experts keep on discovering amazing principles of construction which engineers can adopt for countless technical solutions. This is also the case with self-repairing materials. The self-healing process of the pipevine (Aristolochia macrophylla), a liana which grows in the mountain forests of North America, gave the biologists at the University of Freiburg, Germany, a decisive clue. When the lignified cells of the outer supportive tissues which give the plant its bending stiffness are damaged, the plant administers «first aid» to the wound. Parenchymal cells from the underlying base tissue expand suddenly and close the lesion from inside. Only in a later phase does the real healing process kick in and the original tissue grows back.

Self-healing inflatable structures

This principle is now being transferred to materials – more specifically, to membranes – in a bionics project sponsored by the German Federal Ministry of Education and Research. As soon as a membrane suffers damage, an additional layer provides "first aid", thanks to its mechanical pre-tensioning, closing the hole until a proper repair can be made. This is analogous to the natural process which occurs in lianas. While researchers from the University of Freiburg under the direction of Olga Speck are busy studying the biological and chemical aspects of the model provided by liana plants, Rolf Luchsinger and Markus Rampf at Empa's Center for Synergetic Structures are working on technical solutions for polymer membranes. Luchsinger's impetus, however, concerns neither inflatable boats nor air mat-tresses but rather load-carrying pneumatic structures for lightweight construction. His tensairity beams serve as elements for quickly erected, lightweight bridges and roofing.

The study's goal is to understand under which conditions a hole plugs itself up if the foam expands on a membrane following damage. Within the scope of his dissertation, Rampf is studying this process with the help of an experimental setup which places a membrane under pneumatic pressure and then punctures it with a nail. The researchers have already achieved successful interim results. A two-component foam of polyurethane and polyester suddenly expands when exposed to the excessive pressure which arises when air rushes out of a hole.

«It works in the lab,» notes Luchsinger, «and we're achieving high repair factors.» What does this mean in the real world? Take the case of an air mattress with a volume of 200 litres. Given a certain-sized hole, previously it was necessary to pump it up every five minutes; it now holds for eight hours – enough time to sleep through the night. «We now know enough about the foam that we can enter into discussions with membrane manufacturers about commercializing this technology,» according to Luchsinger, when describing the next steps.

Literature reference

M. Rampf, O. Speck, T. Speck, R. Luchsinger, Self-Repairing Membranes for Inflatable Structures Inspired by a Rapid Wound Sealing Process of Climbing Plants, Journal of Bionic Engineering, 8 (2011) 242–250, doi: 10.1016/S1672-6529(11)60028-0

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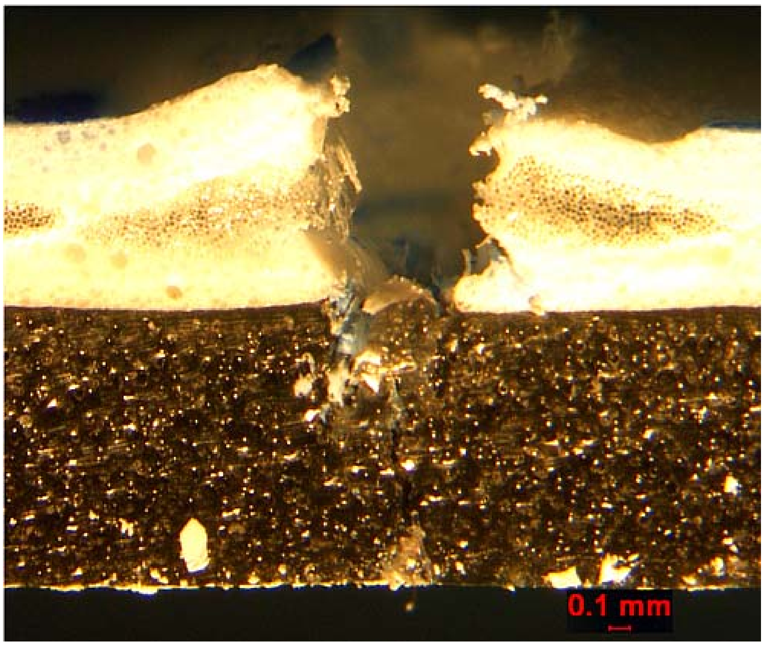
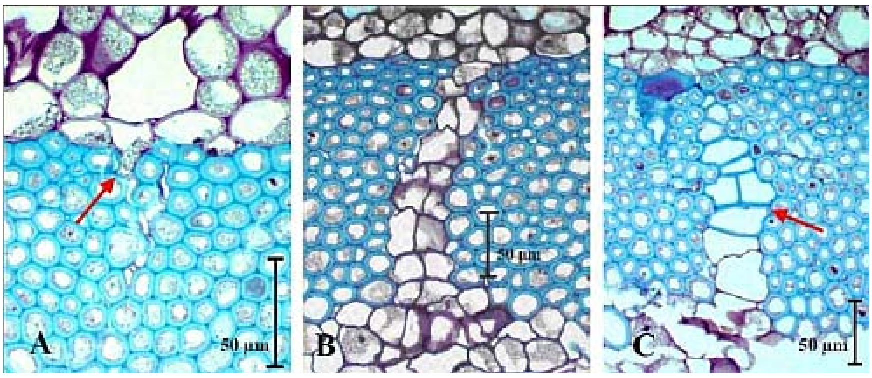


A membrane made of polyvinyl chloride-polyester (yellowish colour) is punctured with a 2.5-millimeter diameter needle, and at that moment the polyurethane foam (brown) suddenly expands. (Photo: Empa)



Cell repair in a pipevine (Aristolochia macrophylla). Parenchymal cells of the base interior tissue sud-denly expand if the lignified cells of the outside supporting tissue are damaged (a and b), and in a later phase (c) they eventually lignify. (Photos: Plant Biomechanics Group, University of Freiburg im Breisgau)

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