Self-healing Materials

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An emerging trend in recent years has been the development and use of self-healing materials. Many drivers are already benefiting from tire products from the likes of Michelin and Continental that utilize self-sealing technologies that work to repair tire punctures without the loss of air on-the-fly. Michelin's Selfseal® technology, for example, uses sealant permanently installed inside the tire to surround the object and fill the hole, preventing air leakage and maintaining pressure.[1]

This is one such technology with which the average person may be familiar. Already in 2019, Ford Motor Company began offering it on factory-installed tires for their 2020 Explorer SUV model.[2] To be sure, even this technology is only meant as a backstop and temporary fix. It is unique, though, in the sense that the technology conducts the repair on its own, without removing the product from service.

Self-healing composites have also long been used for a range of applications, but all have suffered from two practical challenges. Jason Patrick, assistant professor of civil, construction, and environmental engineering at North Carolina State University explains:

> First, the materials often need to be removed from service in order to heal. For instance, some require heating in an oven, which can't be done for large components or while a given part is in use. Second, the self-healing only works for a limited period. For example, the material might be able to heal a few times, after which its self-repairing properties would significantly diminish.[3]

The Next Generation of Self-healing Materials

Patrick is co-author of a research paper just published in Nature Communications that claims to resolve these two practical challenges and significantly extend the lifespan of structural components such as wind-turbine blades.[4] Patrick was interviewed by Nextgov regarding the article, noting that other applicable structural components might include aircraft wings, satellites, automotive components, sporting goods, and so on.

The technology centers on the "glue" that binds laminated composites that are made of fibrous reinforcement layers – for example, glass bonded with carbon fiber. Damage to components often occurs where this "glue" breaks down and causes delamination. The team's approach involves 3D printing a thermoplastic healing agent onto the reinforcement material, as well as embedding a "heater"

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[1] Michelin Website. Michelin® Selfseal® Technology. Available at: https://www.michelinman.com/auto/why-michelin/technological-innovations/michelin-selfseal-technology. Accessed on November 1, 2022.

[2] Phelan, Mark. "2020 Ford Explorer's new tires fix themselves, representing a coming trend for drivers". Detroit Free Press. June 29, 2019. Available at: https://www.freep.com/story/money/cars/mark-phelan/2019/06/29/ford-explorer-self-sealing-tires/1599083001/ Accessed on November 1, 2022.

[3] Shipman, Matt. "New Self-healing Material Fixes Some Key Issues". Nextgov. November 1, 2022. Available at: https://www.nextgov.com/ideas/2022/11/new-self-healing-material-fixes-some-key-issues/379153/ Accessed on November 1, 2022.

[4] Snyder, A.D., Phillips, Z.J., Turicek, J.S. et al. Prolonged in situ self-healing in structural composites via thermo-reversible entanglement. Nat Commun 13, 6511 (2022). Available at: https://doi.org/10.1038/s41467-022-33936-z Accessed on November 1, 2022.

layer in the composite. This heater layer is warmed with the application of an electrical current, thereby melting the healing agent, which is then able to repair composite fractures.

The team sees evidence that this process can be repeated at least 100 times, which alone is impressive. But, it's worth noting that the 3D printed thermoplastic also results in an increase of fracture resistance by up to 500 percent. Patrick says, "[w]hile making composites that incorporate our design would be marginally more expensive, the cost would be more than offset by significantly extending the lifespan of the material."[5]

The Nextgov article author noted another interesting advantage for the use of this new technology in the construction of aircraft wings: *the internal heating elements would allow airlines to stop using chemical agents to remove ice from wings when aircraft are on the ground, and also to de-ice in flight*.[6]

The team's research was supported by the US Air Force Office of Scientific Research and the Department of Defense's Strategic Environmental Research and Development Program. At this point, Patrick noted that they are looking for government and industry partners to help them tailor their technology for specific applications.

[5] Shipman, *op. cit.*
[6] *Ibid.*