Pressurized vascular systems for self-healing materials

September 29 2011

Artificial microvascular systems for self-repair of materials damage, such as cracks in a coating applied to a building or bridge, have relied on capillary force for transport of the healing agents. Now, researchers at the University of Illinois' Beckman Institute have demonstrated that an active pumping capability for pressurized delivery of liquid healing agents in microvascular systems significantly improves the degree of healing compared with capillary force methods.

In a paper for the *Royal Society journal Interface*, Nancy Sottos, Scott White, and former graduate student Andrew Hamilton report on their investigation into using an active pumping method for microvascular systems in a paper titled Pressurized vascular systems for self-healing materials. Their inspiration, they write, comes from the fact that nature in its wisdom gives that ability to many biological systems: "Fluid flow in these natural vascular systems is typically driven by a pressure gradient induced by the pumping action of a heart, even in primitive invertebrates such as earthworms."

Sottos and White, faculty in the College of Engineering at the University of Illinois, and their fellow collaborators from Beckman, have developed different methods for self-healing, including microvascular systems for self-repair of polymers. The vascular system works when reactive fluids are released in response to stress, enabling polymerization that restores mechanical integrity.

For this project, Sottos, White, and Hamilton sought to determine the effectiveness of an active pumping mechanism in a microvascular system because, they wrote, relying on capillary flow to disperse the healing agents, "limits the size of healable damage," and because "unpressurized delivery of healing agents requires diffusional mixing -- a relatively slow and highly localized process for typical resin-hardener systems -- to occur for the healing reaction to initiate."

To achieve active pumping the researchers experimented with an external "pump" composed of two computer-controlled pressure boxes that allowed for more precise control over flow. The healing agents in the pump were fed into two parallel micro-channels. They found that active pumping improves the degree of mechanical recovery, and that a continuous flow of healing agents from dynamic pumping extends the repeatability of the self-healing response.

"Significant improvements," they write, "are achieved in the degree of healing and the number of healing events possible, compared with prior passive schemes that utilize only capillary forces for the delivery of healing agents."

Sottos said the study was a first step toward integrating active pumping into microvascular systems.

"This set-up could be used with any microvascular network, including the structural composites reported on recently," Sottos said. "In future materials, it would be ideal to have the pumping integrated in the materials itself.

"The advance of this paper is the study of active pumping/mixing for healing. We haven't applied this to healing with the structural composites yet; the present study was essential to understand what happens when we pump the healing agents."

Provided by Beckman Institute for Advanced Science and Technology