UF-developed detectors help guard against foam flaws in shuttle's fuel tank

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The engineers who built the massive external fuel tank that will power the shuttle Discovery into orbit this spring used sophisticated X-ray detectors developed by UF researchers to reduce the chance of a defect in the foam insulation covering the tank. The detectors, first invented as a new technology to find land mines, can identify tiny gaps, or air-filled voids, in the insulating foam without causing any damage. It is believed that such a gap – possibly located between the foam and the tank's surface – caused a suitcase-sized piece of foam to break off during Columbia's liftoff in January 2003. The chunk struck the edge of the shuttle's left wing, seriously damaging it and spurring the shuttle's destruction during re-entry on Feb. 1.

"We can do the inspection of the foam as it exists already sprayed onto the tank. We don't have to cut into it," said Warren Ussery, team leader for the return to flight nondestructive evaluation team at Lockheed Martin's Michoud Assembly Facility in New Orleans, where the shuttle's external tanks are manufactured. "We're able to find critical voids with that (the UF detector)."

UF nuclear engineering professor Ed Dugan and retired UF nuclear engineering professor Alan Jacobs began experimenting with the modified "backscatter" X-ray detector several years ago as part of research aimed at engineering a more effective landmine detector. Conventional X-ray machines propel radiation through a target object to radiographic film on the other side. Different objects absorb X-rays to differing extents, so some show up more prominently on film than others. Backscatter X-ray machines were developed for circumstances when it is impossible to place film behind the object, as is the case with the shuttle tank. Contrasting conventional machines, they obtain images by capturing the radiation scattered "back" from the target.

Dugan said conventional backscatter detectors select only the radiation -- which takes the form of photons – that has had a single collision with the target object. The detectors ignore "multiple-collision" photons, which may have hit the target several times, because with conventional image processing, they tend to cloud the image. One of the unique advantages of the UF-built machine is that it draws useful images from these multiple-collision photons, he said.

"There's a lot of good information in multiple-collision photons, but learning how to use it was not trivial," Dugan said. Twin detectors pick up photons from both single- and multiple-collision photons, with a computer merging the two using complicated computer-processing algorithms. In U.S. Army-sponsored tests, the technology proved adept at locating landmines, but the images were equally striking because they showed tiny empty spaces in the mines themselves.

"The photons would zip across the voids and bounce back," Dugan said. "It allowed us to tell mines from tree stumps and stones, because we had high intensity areas where the voids were."

Jacobs and Dugan realized this capability made the detectors ideal for identifying flaws and defects in materials such as the carbon fiber used in airplanes without having to rip the material itself apart. The first tests of the concept, done on airplane frame members and small components, proved promising. After the Columbia disaster, word of the positive results led to an inquiry from Lockheed Martin.

For preliminary testing purposes, the aerospace giant provided the UF researchers with sample chunks of fuel-tank foam containing known flaws as well as samples with unknown flaws. Some of the foam pieces were melded to the aluminum skin of the fuel tanks, while others consisted solely of foam. The UF detectors identified all significant flaws both within the foam and lying between the foam and the fuel tank skin.

"The flaws we found ranged from a quarter inch to 2 inches, and they were both de-laminations and voids," Dugan said.

The defense contractor then purchased four of the roughly $100,000 scanners, while NASA bought one.

Ussery said Lockheed has used the detectors, in tandem with a private company's scanning technology called tetrahertz imaging, to scrutinize the foam on a roughly 100-square-foot section of Discovery's external fuel tank as well as a back-up tank.

That's a tiny swath of the overall tank, which is 154 feet long, 27.6 feet around and has a total area of 12,620 feet -- so large it has to be transported from New Orleans to Kennedy Space Center by ocean-going barge. However, the section, located on a ramp that protects instrumentation during flight, is covered with relatively thick foam applied by workers rather than machines. With parts as thick as 7 inches, versus 1 or 2 inches elsewhere, that raises the risk of an air bubble void.

The foam chunk that broke off Columbia was also hand-applied. But in the new tank, the area where the mishap occurred -- a bipod fitting that connected the tank to the orbiter -- is no longer covered with foam. Instead, heaters do the job the foam once performed.

Ussery said Lockheed engineers scan about 1 square foot per hour using the backscatter X-ray machine. The machine can work about at about twice that speed, but the image resolution and ability to detect small gaps declines at high speeds, Dugan said. Lockheed engineers used the machine to seek out flaws near the surface of the foam, while they employed the tetrahertz imaging machines to probe deeper. Neither machine found any flaws big enough to warrant removing the foam, Ussery said.

Source: University of Florida

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