FEATURE

Structural health monitoring: composite skins are getting a nervous system

Django Mathijsen

Django Mathijsen discusses structural health monitoring (SHM) and how it is entering real world applications.

Imagine not needing testing or measurement equipment to assess how much wear and damage a composite structure has sustained. Just plug your laptop into the component and its built-in sensors tell you if it needs replacing. That's what structural health monitoring is promising for the future. But it takes a lot of research to make it work.

Structural health monitoring (SHM) is integrating sensors into a composite component so you can real time measure if it is still functional and safe. The concept of SHM was first applied in civil engineering: attaching sensors to steel and concrete structures like bridges and buildings, especially in earthquake sensitive areas.

The field is shifting to composites, and applications like aerospace and wind turbines. But the technology cannot easily be transferred. In composites the damages are of a different order. And the structures tend to be more complex, as well as the damage: it can be internal and is influenced by fiber orientations.

Still, the technology is close to leaving the laboratory and entering real world applications.

Fast and effective damage analysis

''You can measure anything that will give you information about the performance of a structure,'' says Richard Loendersloot of the University of Twente about SHM. ''Temperature in bearings for example. But we are especially looking at dynamic behavior, measured for example with strain gauges.''

The university is participating in the project Wibrate (http://wibrate.eu/), integrating SHM in a helicopter rotor and in milling machines for the automotive industry. They are cooperating with NLR (the Dutch National Aerospace Laboratory) to develop SHM for fixed wing aircraft. And they are looking at implementing SHM in composite aircraft panels with Airbus in the project Saristu (http://www.saristu.eu/).

''The aim is to get to a higher technology readiness level,'' Loendersloot says. ''So we are initially limiting the level of SHM. For example I am investigating a monitoring system for the composite parts around a door surround in an aircraft (together with the partners of the Saristu project). There is a lot of traffic around the doors when an aircraft is stationary. So the impact risk is high. If an impact happens, you need fast and effective damage analysis.''

Detecting invisible damage

Composites are being used more in airplanes, like the Boeing 787 and Airbus A350. ''Composites have many advantages, like low weight and high stiffness and strength, but a disadvantage is that you cannot see internal damage on the outside,'' says Ted Ooijevaar who earned his PhD at the University of Twente for an SHM system to monitor composite skin-stiffener structures, a common construction in the aircraft industry.

Aircraft maintenance crews use the ''Barely Visible Impact Damage'' criterion: if you can't see any damage under typical lighting conditions from a distance of five feet, the structure is still good to fly. Fine for metal structures, but not for composites.

''Internal damage, invisible from the outside, can have significant consequences,'' says Ooijevaar. ''Delamination for example between a stiffener and the skin. So one reason for developing SHM is to be able to guarantee the integrity of the structure. A second reason is: if you exactly know when a part will fail, you can go from maintenance at fixed periods to maintenance as needed. My research was financed by the European project Cleansky (http://www.cleansky.eu/), which focuses on the development of breakthrough technologies to improve the environmental performance of airplanes. That's the third reason: if I can measure the behavior of the structure, I may be able to lengthen its working life.''

Embedded sensors

Maintenance crews need specialist knowhow and equipment (like ultrasonic scanners) for assessing internal damage. SHM means

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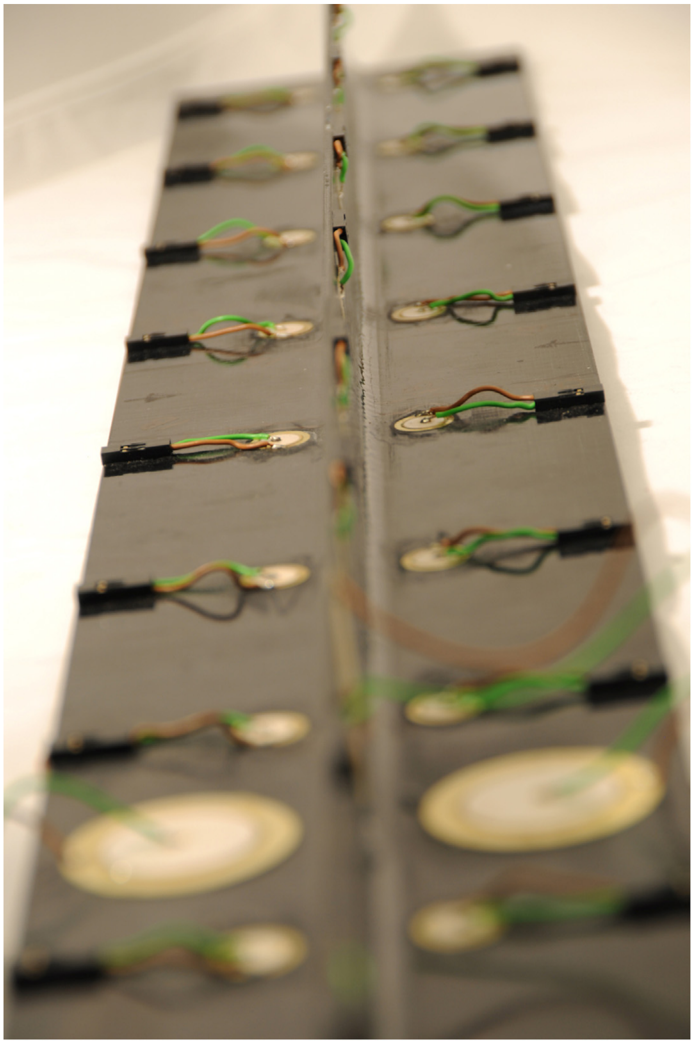


integrating sensors into the structure so you only have to plug in a laptop, which will run a measurement cycle and tell you if the structure is healthy.

Integrating the sensors instead of sticking them on increases their chemical and mechanical resistance. ''And you can use them for quality control during and after production,'' Ooijevaar adds.

Don't the embedded sensors weaken the part? ''Not if you do it right,'' Loendersloot answers. ''In composites it's a matter of not disturbing the intended path of the fibers. If the sensor pushes fibers aside, especially if they are under an angle, you have a problem.''

Critics have other qualms about integrated sensors. They increase the cost of a component. And if a sensor breaks, should you replace the whole component?

''No manufacturer wants an aircraft with sensors everywhere,'' says Ooijevaar. ''So I think SHM will mainly be used for hot spot monitoring.'' From the design you know where the part is likely to fail critically first: that's where you want sensors.

Chiefly piezoelectric elements are used for the strain gauges. They require wires coming out of the component: creating a robust connection is a challenge.

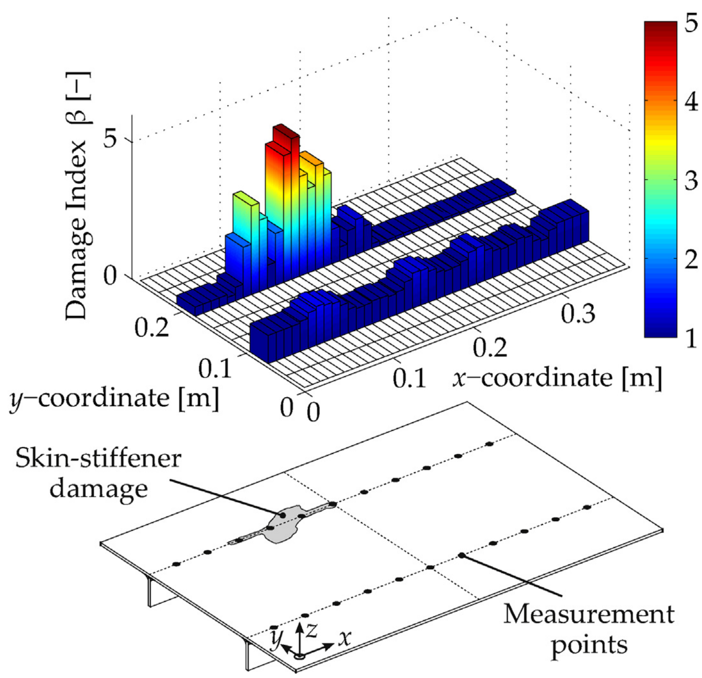
''A wire can break, especially if it is long,'' Loendersloot says. ''You might prefer to process the data in a small processor near the sensors, and maybe send the results wireless to a central unit. We are working with such a wireless node in the Wibrate project. The processor can also accept commands from the central unit. Wire sensors on the other hand give you more freedom with algorithms. So SHM requires an integrated design process.''

They are also looking at using SHM in wind turbine blades to prevent blade breakage. There, wireless data transfer from the rotating to the static part has big advantages.

Going wireless offers its own challenges, like the power supply: do you install a battery or can you harvest energy?

Another way of reducing the number of wires is to use an optical fiber Bragg grating: a fiber that can contain multiple sensors. It has a local periodical variation in the refractive index of the fiber core, acting as a wavelength-specific mirror. The reflected frequency changes as the fiber is strained. These fibers offer other challenges.

Skin-stiffener structures, a common construction in the aircraft industry.



A skin-stiffener damage index distribution.