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A DEEPER LOOK INTO THE COMPONENT
Terahertz sensors test modern aircraft materials

MATERIALS TESTING

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Today, energy savings isn't only a pressing development goal in the automotive industry – it also applies to aircraft construction. Manufacturers therefore increasingly turn to modern alternative materials – such as carbon and fiberglass compounds – in addition to traditional materials like aluminum. They are elastic, stable and very light at the same time. These materials reduce aircraft weight and kerosene consumption along with it. For example, the Airbus A380 consists of at least 20 percent carbon-reinforced plastics (CRP).

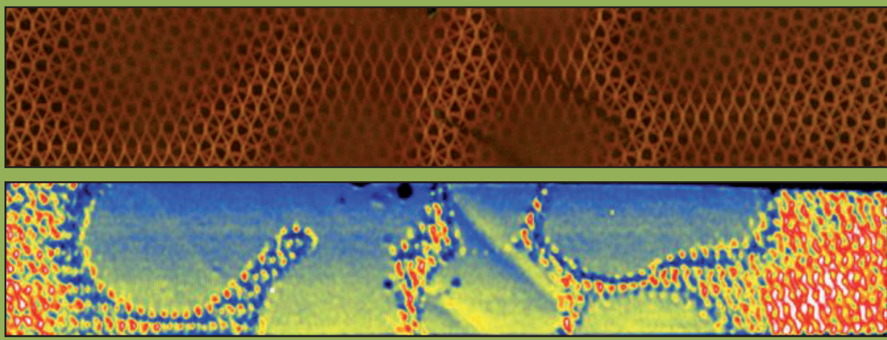
Aircraft construction must adhere to high safety standards. Therefore manufacturers meticulously check every material and every component during production. However, traditional testing methods are not fully suited to new high-tech materials. Ultrasound more or less fails when it comes to probing fiberglass compounds. These sandwiches of material consist of several layers of plastic resin and fiberglass fabric. The layer structure scatters the ultrasound waves such that they cannot be detected and evaluated, so material defects can no longer be recognized. In past years, researchers from Fraunhofer IPM have brought a new testing method to market that ideally supplements the conventional methods: a measuring system using terahertz (THz) waves. This involves electromagnetic radiation, whose wavelength lies between that of microwaves and infrared radiation. These terahertz waves penetrate many electrically non-conductive materials.

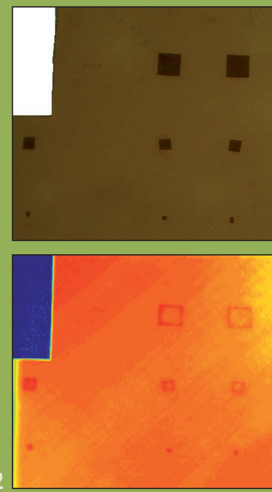
In aircraft construction, composite materials are increasingly used to save weight. These innovative materials demand new testing methods. Terahertz waves can be used here as a good addition to existing nondestructive testing methods. *(Image source: Airbus S.A.S.,2008, e[x]m company, H. Goussé)*

THz waves identify foreign objects, air pockets and material layers

IPM researchers have already developed a system for testing wind turbine rotor blades, and they are now working on a scanner for aircraft components. The system is one result of the joint European project DOTNAC (Development and Optimization of THz Non-destructive testing on Aeronautics Composite Multi-layered Structures), which the EU is funding as part of the seventh support program (RP7). The measuring system consists of small terahertz transmitters and receivers that are each the size of a soft drink can. In the future, robots or other automated machines will guide the devices over a component. The transmitter sends terahertz waves through the work piece, and the receiver measures the reflected signals. Depending on different material properties, portions of the terahertz wave are reflected at every material change. The terahertz echo can even be used to realize when material changes unexpected by boundary like detecting hollow areas or inclusions. For weight-saving purposes, hollow structures are often used in aircraft construction, and these can be tested outstandingly with terahertz technology. Even defectively adhered areas are reliably detected.

The focus of the project is what is called the »radar dome«, an aircraft's round nose through which radio signals are emitted and received. It is made of fiberglass composite. During future production, the testing system should monitor whether foreign objects, water droplets or air bubbles have become trapped as the resin hardens. With time, at this type of defect location,





1 *A section of a stringer made of CRP with lightning protection applied (above). The areas with embedded lightning protection appear dark. The maximum amplitude of the reflected THz signal (below) clearly shows the areas with embedded lightning protection and surface defects (cracks and holes).*
(Image source: Fraunhofer IPM)

2 *A plate made of fiberglass-reinforced plastic with artificially induced defects (PTFE foil) serves as a reference sample. The reference plate's absorbed reflection shows all introduced defects.*
(Image source: Fraunhofer IPM)

fine cracks can form that allow penetration of moisture. This disturbs radio communication through the aircraft nose, and the signals are attenuated strongly.

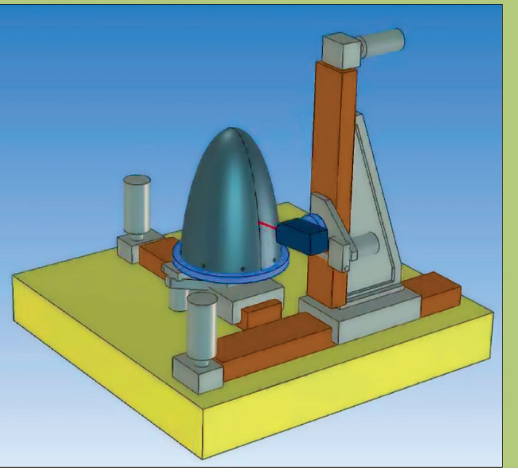
Checking paint thickness, layer by layer

The scanner will even make painting aircrafts easier. Aircrafts receive several successive coatings of paint – a base coat applied directly to the component, the top coat and the clear coat. Once the procedure is over, a large commercial aircraft carries half a ton of paint through the air. And these layers also contribute to fuel consumption. Up to now, aircraft parts have been weighed before and after painting. If too much paint is accidentally applied, the coating has to be removed completely and the coating will be repeated. That wastes time and especially money. With the terahertz procedure, the layer thickness can be directly monitored while painting is going on. Even the thickness of each individual paint layer can be determined exactly. This allows the painting system to be appropriately controlled. Conventional devices for measuring paint thickness, which work by the eddy current or ultrasonic process, can't be used due to the required physical contact and are mostly limited to measure the total thickness of all paint layers on a component only. Furthermore, the eddy current process is suitable only for metals, and not for modern CRP fiberglass compounds.

Thickness is also important when it comes to lightning protection. Traditional metal aircraft parts dissipate the energy from lightning perfectly, but it's different with modern plastic compounds. Their conductivity is considerably lower. This means that when lightning strikes, the component can get very hot and sustain damage. For the electricity to dissipate better, a composite component is therefore overlaid with a stretched copper foil. This is embedded into the outer plastic resin layer before the resin hardens.The manufacturer must ensure with great precision that the foil does not sink too deeply into the resin, so that the electrical charge from lightning won't penetrate too deeply into the component. This is where the coating thickness comes in: The coating layer must also be thin, so that it doesn't shield the copper foil too much. Here also, the terahertz process helps. Because it determines the total thickness of the resin and paint during application, it can tell in real-time whether the layers over the foil are thin enough.

»X-ray vision« without X-rays

For a long time, not much attention was paid to terahertz waves. Only in the past 10 years people have recognized their potential and begun to use the technology in industrial applications. The advantages are obvious: Terahertz waves are completely harmless to people, because they are non-ionizing and the power level is very low. This does not hold for X-ray radiation still commonly used in aircraft construction. Aircraft components are X-rayed because it allows



3 *Testing system design for a »radar dome«: The radar dome can be seen in the middle of the picture, and the scanners are mounted around it. The terahertz measuring head is shown in dark blue.*

(Image source: DOTNAC Project)

extremely fine imperfections of a few hundredths of a millimeter to be detected. This, however, means evacuating the entire work hall, so that the employees are not exposed to harmful radiation. This is quite expensive. A terahertz scanner, on the other hand, would do no harm to the workers and could substitute X-ray inspection in some cases.

Terahertz sensors – a sensible supplementary technique

Fraunhofer IPM developers assume that terahertz technology will be used in combination with other methods, for example with thermal imaging sensors. Within a few seconds, a thermal imaging sensor captures an area of one square meter. This provides a very good overview. However, depth information obtained in this way is too imprecise. A terahertz sensor would be the ideal addition: Although, the lateral resolution of about one millimeter is relatively low, its depth resolution of a few micrometers is nonetheless remarkable. Future materials testing devices will be combinable with various sensor types. With sensors merged in this way, first the thermography module would make a rough scan of the components to detect suspicious areas in the material. Then the terahertz scanner would put these under the magnifying glass a few moments later.

The DOTNAC project ends in the summer of 2013. By then, the 10 international collaboration partners hope to have a demonstration model developed and thoroughly tested. The developers assume that a marketable terahertz scanner or combination device that unites several sensor technologies may be ready about a year later.

DOTNAC project participants at Fraunhofer IPM include: René Beigang, Joachim Jonuscheit and Simon Kiefhaber, with Carsten Matheis as project leader.

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