NDT OF SPECIAL HONEYCOMB STRUCTURES BY USING MICROWAVES

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Abstract

For lightweight design of aerospace parts sometimes honeycomb structures are used, which are filled with epoxy resin and hollow glass microspheres. The necessary testing for pores can be done by X-ray techniques. This is of high effort and therefore expensive. Microwave non-destructive testing seems to be a candidate for a less expensive NDT method. In order to prove this, tests were performed at a model part.

This concerns a honeycomb plate with transversal dimensions of 250 mm x 80 mm and a thickness of 36 mm. The cell width is 4.8 mm, the hollow glass microspheres have an outer diameter of 80 µm to 100 µm. Besides of clusters of “natural” defects there are “artificial” blind holes in the plate with diameters ranging from 1.0 mm to 2.0 mm and residual wall thicknesses from 14 to 24 mm. Preliminary tests were performed with various waveguide type and lens type antennas between 24 GHz and 40 GHz. This report describes reflection tests with a lens type antenna and transmission tests with waveguide antennas.

In the reflection tests at 35 GHz with a lens antenna the sample was scanned in meandering pattern from the completely filled side. Modulus and phase were used to evaluate the data. To optimize the representation of the indication the projection phase was varied. In this way all known and additional defects were recognized. It is shown, how in cases of doubt it may be helpful to inspect more closely the local surrounding of the indication in the complex plane of the reflection coefficient.

The transmission tests were performed at 24 GHz with two open ended rectangular waveguides as receive and transmit antennas. These tests also gave indications of most of the defects. However, the clearness was somewhat reduced by interference signals.

As a conclusion: The suitability of microwave testing is confirmed for the described type of honeycomb structure.
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7th International Symposium on NDT in Aerospace
November 16-18, 2015 in Bremen, Germany

1. Introduction
2. Test setup
3. Test results
4. Conclusions

Honeycomb plate with filling.
Test as a feasibility study:
Completeness of filling to be determined

- plate dimensions: 250 mm x 80 mm x 36 mm
- NOMEX® honeycombs with cell width 4.8 mm
- filling with Epoxy and hollow glass micro spheres, diameter from 80 µm to 100 µm
- applications in aerospace engineering
- „natural“ defects: incomplete filling
- „artificial“ defects: blind holes
  with diameter/remaining wall thickness/length of hole in mm:
  top from left: 1.0/18(18), 1.5/8(28), 2.0/18(18)
  bottom from left: 1.5/18(18) und 1.5/12(24)
Probes (antennas) in microwave testing

- Coaxial probe for high spatial resolution
- Waveguide probe for larger observation depths
- Open waveguide and lens for observations depths up to 60 mm

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Test system with lens antenna and microwave network analyser

- Reflection method:
- Transmission method: open waveguide as transmit and receive antenna

Test setup with lens antenna, honeycomb plate, network analyser, and x,y stage

Details of test setup:
- From bottom: microwave absorbing mat (black), honeycomb plate, lens, open waveguide as primary radiator
User interface of the program Scanmaster3000 for microwave testing

Example:
Test frequency 24 GHz
Reflection method
Poly carbonate plate
300mm x 300 mm
4 mm thick
Blind holes mit
diameter/residual wall
thickness in mm
5.0/0.0 3.0/0.0 2.0/0.0
5.0/1.5 3.0/1.5 2.0/1.5
5.0/3.0 3.0/3.0 2.0/3.0

Left: 2D (C-scan type) and 1D (B-scan type) display of magnitude, phase, real part, or imaginary part
Middle: adjustment of projection phase, amplification, filtering, grey/rainbow etc.
Right: curve of reflection coefficient in the complex plane along the cursor line in the 2D display (left)

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Transmission Method

- frequency: 24 GHz
- T/R antennas:
  - open waveguide
- spatial low pass filter in vertical direction
  > the rim at the bottom is cut off
- discovered: blind holes 1.5/8(28); 2.0/18(18); 1.5/18(18) and 1.5/24(12) as well as visually detectable clusters. Furthermore: indications of unknown origin
- not discovered: blind hole 1/18(18)
Reflection method, 35 GHz, lens antenna, test from not-drilled side

Set 1 of evaluation parameters
- discovered: blind holes 1.5/8(28); 2.0/18(18); 1.5/18(18) and 1.5/24(12) as well as visually detectable clusters. Furthermore: indications of unknown origin
- at first not discovered: blind hole 1/18(18)

Set 2 of evaluation parameters
- missing blind hole 1/18(18) is discovered.

Result:
- all "artificial" defects are discovered
- strongest signals from 1.5/8(28) und 2.0/18(18)
- weakest signal from 1/18(18)
Detailed examination in case of suspicion,
reflection coefficient in complex plane

Details of the indications and further irregularities in the interior of the part are discovered.

Curve of reflection coefficient along the green line

Conclusions

- Component: Honeycomb plate, 36 mm thick, filled with epoxy and hollow glass micro spheres
- Feasibility study. Task: Discover deficiency of filling by use of microwave testing
- Result: All known defects have been discovered as well as further defects which were not known before.
- The results of the reflection method are clearer than those of the transmission method.
- In the reflection method: stronger indications from defects which are more voluminous and nearer to the probe
- Microwave testing can successfully be used for this task. There are no safety concerns as they are for example with X-ray testing.
  There is no need for couplant as it is often required for ultrasonic testing.

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