Nondestructive testing of polymer composite materials using THz radiation

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Abstract. This paper shows an ability to find internal defects in construction of polymer composite material using THz imaging. Using THz vision system resulted in an example of finding internal non-impregnated area in fiberglass.

1. Introduction and background

Terahertz radiation could have the unique ability to penetrate composites and identify defects such as voids, delaminations, mechanical damage and others [1]-[5]. The ability of finding heat damage in aircraft polymer composite materials, acquired during operation, by THz time-domain spectrometer (TDS) was studied in [1]. This work shows the ability of non-destructive control of technological defects, like non-impregnated area, in polymer composite materials, reinforced by glass fiber, by using THz continuous wave (CW) scanning vision system.

2. Results

Results of modeling operation of the CW vision system are shown in the figure 1. Interaction of THz radiation with construction of polymer composite material model was modeled by means of numerical solution of Maxwell's equations by finite-difference time-domain (FDTD) method.

Discretization parameters of space and time coordinates:

$$\Delta x = \Delta y = 0.003\, mm$$

$$\Delta t = \frac{\Delta x}{c\sqrt{2}} = \frac{\Delta y}{c\sqrt{2}} = 7.02\ fs$$

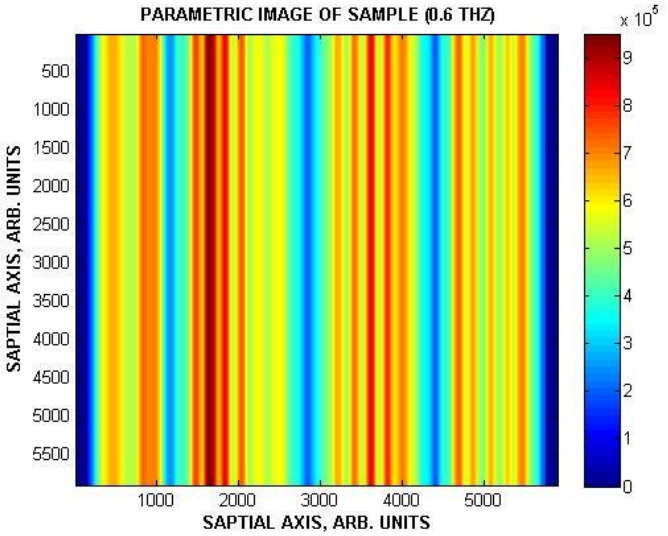

Figure 1. Modeling result of the THz vision system work, results are presented as form of parametric images.

Figure 1 presented the reflected from the sample model wave registered at an arbitrary distance from the surface of the object. Clearly visible irregularities reflected field in the areas of defects. Also it can be clearly seen that the deeper the defect area is placed the lower contrast of the image becomes.
Construction model includes an ordered arrangement of fiberglass filaments, with a diameter 60 μm, placed in the polymer matrix. The model includes three simulated cylindrical defects, with a diameter 900 μm, as shown in the figure 2 and figure 3.

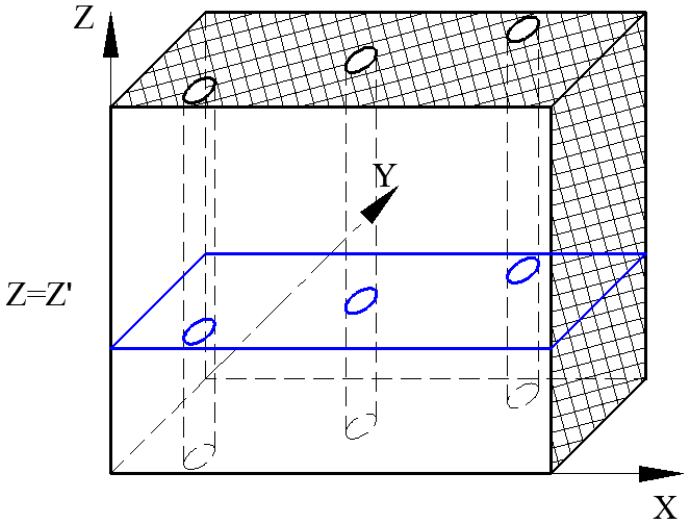

Figure 2. Product model of a polymer composite reinforced with fiberglass.

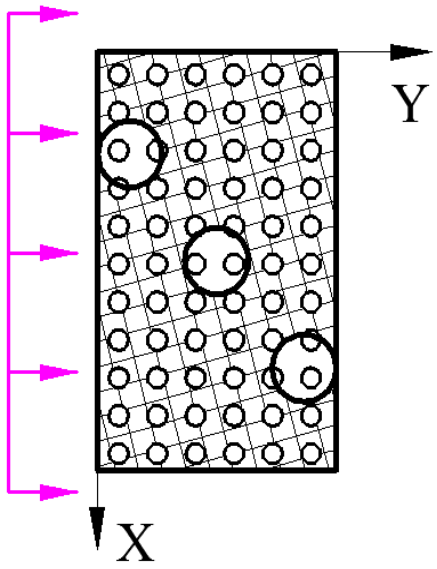

Figure 3. Cross-section Z=Z' of the model.

To verify experimentally the result of modeling, a sample of polymer composite material glass fiber reinforced was studied.

Several defects were simulated in the sample (figure 4). Defects are linear non-impregnated area, with the dimensions: length 15 mm width 3 mm depth 2 mm. THz radiation wavelength used for the control of sample quality was 1 THz.

The figure 5 showed result of scanning a sample of this polymer composite materials. The experiment was performed on the scanning THz CW vision system.

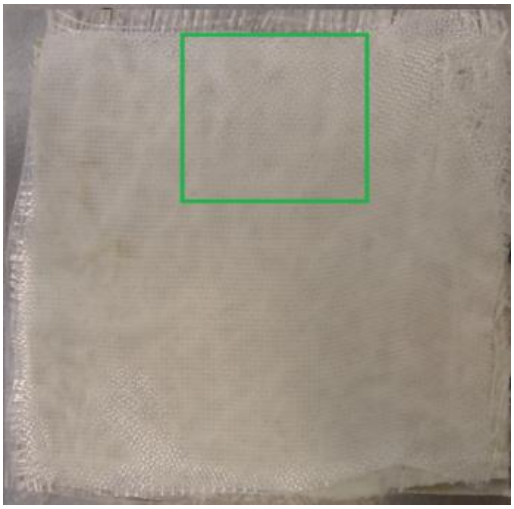

Figure 4. The sample of polymer composite material reinforced by fiberglass, with simulated defects. (scan area is highlighted in green).

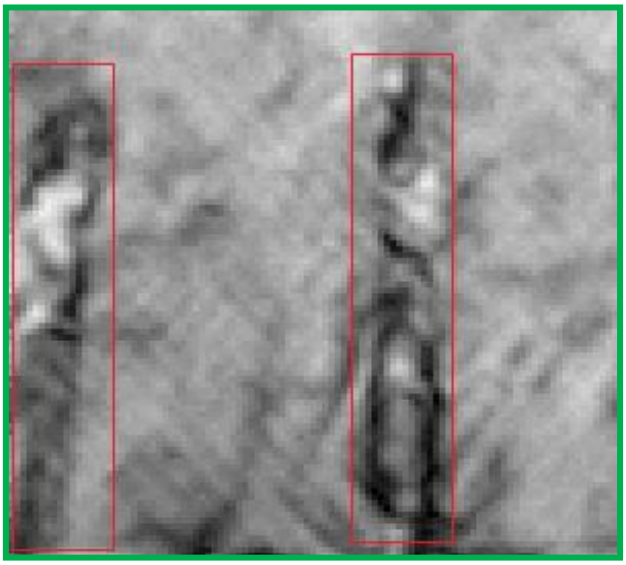

Figure 5. The result of scanning a sample of polymer composite reinforced by fiberglass using THz vision system,presented in the form of images (the defect area – non-impregnated stripes – is highlighted in red).

A potential of THz CW imaging system to detect the defects in polymer constructions was studied numerically and experimentally. Obtained images showed that such defects as non-impregnated area can be imaged clearly.

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