DELFT UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF AEROSPACE ENGINEERING

Report LR-227

AN ULTRASONIC SCANNING TECHNIQUE WITH ADJUSTABLE SENSITIVITY LEVEL SETTINGS FOR QUALITY CONTROL OF ADVANCED COMPOSITES

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ABSTRACT

In this note an ultrasonic scanning technique is presented that can be useful for the determination of the quality of advanced fibre reinforced materials. The use of a number of adjustable detection levels offers the possibility of displaying a semi continuous absorption plot. Contrasting failure marks can be generated to simplify the interpretation of the scanned pictures. Some fibre reinforced panels also in combination with aluminium and aramidfibre faces have been tested and the results are discussed.

INTRODUCTION

When transmitting an ultrasonic beam through a material there will be energy loss through the thickness by absorption and dispersion. In fibre reinforced materials discontinuities as voids and delaminations will cause serious energy losses, which results in a low amplitude of the received signal. By scanning the material with an ultrasonic beam and simultaneously recording the value of the signal amplitude an absorption pattern is obtained.

SIGNAL PROCESSING

To form a signal than can be processed automatically the transducer signal is amplified, rectified and integrated, see figures 1 and 2. A Sperry pulser receiver unit has been used but most of the commercial ultrasonic receiver amplifiers will give satisfactory results. The amplified signal is compared to ten detection levels, each representing a grey-tone on a display. By varying the detection levels these grey-tones can be adjusted to cover the total amplitude range of the received signal. It is also possible to set the detection levels in such a way that certain defects will be indicated by a large grey-tone contrast. The test set up is illustrated on page 2. It can be simply realised with TTL-
components. The sound-absorption pattern is displayed on an oscilloscope and recorded by a Polaroid camera.

Figure 1
Transducer signal

Figure 2
After detection

TEST SETUP

Figure 3. Schematic diagram
When the received signal exceeds a variable DAC level, the counter counts up and the DAC level rises one step. When the received signal is below the DAC level the gate opens and the transmitter signal causes count down. The variable DAC level is thus continuously following the signal amplitude. Each of the ten level numbers has a fixed greytone on the display that is not affected by the level settings.

APPLICATIONS

By an appropriate choice of the level distribution a range of applications can be realized as shown in figure 4.

Examples of level settings:

<table>
<thead>
<tr>
<th>Maximum signal</th>
<th>Minimum signal</th>
<th>Normal detection</th>
<th>High contrast flaw or failure detection</th>
<th>Thickness testing</th>
<th>Testing with a high resolution in a specific area</th>
</tr>
</thead>
</table>

Figure 4

a.  
b.  
c.  
d.

In the first case (fig. 4a) the levels are equally distributed between the minimum signal (maximum absorption) and the maximum signal (no absorption). A better sensitivity for specific application can be obtained by more concentrated level settings (figs. 4b-d).

In fig. 4d the levels are concentrated in a smaller amplitude range, but the distribution in the range is still homogeneous. In fig. 4c more levels are concentrated at the upper and lower end of the amplitude range. This setting is suitable especially to give large contrast variations of the grey-tones if the thickness is outside a required thickness range. If flaws or failures causing more absorption are to be indicated the level setting of fig. 4b should be preferred.
RESULTS

Several panels were produced in the Composites Laboratory of the Aerospace Department of the University of Technology in Delft and by the Product Development Department of Fokker VFW in Amsterdam. Figures 5 to 9 show the results of the ultrasonic examination of these panels. The pictures 5 to 8 cover an area of 15 x 22 cm. Picture 9 is a combination of several photographs. The line direction is about 1/3 millimeter.

Figure 5 shows an absorption plot of a unidirectional carbonfibre-epoxy panel. The fibre orientation is horizontal. When curing a solvent containing resin a large amount of voids is formed. The black spots are due to absorption by such voids. Differences in thickness are also clearly located. The left and right edges show a high fibre content (small thickness) and few voids due to horizontal bleeding.

Figure 6 shows the picture obtained if the same panel is scanned with a high contrast level setting (fig. 4b). Then voids are clearly indicated. The smaller black spots are voids of a size less then one square millimeter.

The panel in figure 7 shows the damage of impact testing on a laminate consisting of 2 layers Kevlar 181 $\pm 45^\circ$

6 layers CFRP $0^\circ$, $\pm 60^\circ$

Dark spots with sharp edges indicate delaminated areas were a steel ball stroke the surface. Other dark areas indicate void concentrations formed during manufacturing.

Fig. 8. By concentrating the level settings halfway between the minimum and the maximum receiversignalamplitude (fig. 4d) a large contrast between the highest and the lowest amplitude in a relatively homogeneous panel is achieved. This technique was used to check the fibre alignment which is poor in this panel. The fibres are not fully parallel but follow curved lines.

Material: Aluminium-CFRP-Aluminium.
The described method offers a good possibility for testing of carbon-fibre-epoxy faced honeycomb structures. Ultrasonic energy is transmitted through the core material. If the bond between the face and the core is defective, absorption will occur. Figure 9 shows a panel in which bond failures were deliberately produced. This panel was inspected and the result is presented in figure 10.

CONCLUSIONS

The method gives an excellent overall view of material homogeneity and fibre directions even when carbon-epoxy laminates are combined with aluminium or aramidfibre faces. Voids of about one square millimeter can be detected. By using a high transmission repetition frequency fast scanning is possible and large panels can be tested in a relatively short time. The use of high contrast void and failure detection is attractive for quality assurance during production.
Figure 5
Carbonfibre epoxy unidirectional laminate with high void content.
Figure 6

The same panel as in figure 5, now scanned with high contrast.
Figure 7

Cfrp aramid mixed laminate with impact damage.
Figure 8

Carbonfibre reinforced epoxy panel with poor fibre alignment.