SOME INVESTIGATIONS INTO ULTRSONIC DIAGNOSTICS APLICABILITY FOR COMPOSITE STRUCTURE

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Summary

Authors present results of their investigations into diagnostic applicability of the ultrasonic NDT systems developed by them for composites inspection. The attention was focused on the methods of visualization of the defectoscopy results. There were tested composite specimens, subjected earlier to fatigue or impact loads. Presented results proves effectiveness of ultrasonic NDT methods in detection of such defects as delamination or disglueing, and partly effectiveness in the investigations of fatigue processes of the composite structure reinforced by fibers. A low effectiveness was observed in case of investigating degradation of glue connection type *metal-composite*, which occurs in the whole volume of the glue layer in cohesive way.

Keywords: composites, delaminations, ultrasonic diagnostics.

BADANIA NAD ZASTOSOWANIEM DIAGNOSTYKI ULTRADŹWIĘKOWEJ W BADANIU STRUKTUR KOMPOYTOWYCH

Streszczenie

Autorzy przedstawiają wyniki prac badawczych z użyciem opracowanych przez nich systemów defektoskopii ultradźwiękowej. Nacisk został położony na metody wizualizacji wyników diagnostyki. Badaniom poddawano próbki kompozytowe stanowiące obiekty badań zmęczeniowych lub udarowych. Zamieszczone przykłady wskazują skuteczność metod ultradźwiękowych w wykrywaniu takich wad jak delaminacje lub rozklejenia, a także częściową przydatność w badaniach procesów zmęczenia struktury kompozytów włóknistych. Małą skuteczność zaobserwowano natomiast w przypadku badań degradacji zmęczeniowej sklein typu *metal-kompozyt*, zachodzącej całej masie polimeru skleiny w sposób kohezyjny.

Słowa kluczowe: kompozyty, delaminacje, rozwarstwienia, diagnostyka ultradźwiękowa.

1. INTRODUCTION

Trends to maximise the profits of airtransportation companies generate needs for implementation a maintenance model according to the real technical conditions. This model is going to replace still existing, non-economical maintenance model according to a service life, guaranteed by the producer. The maintenance model according to technical conditions is implement able only in case of parallel implementation of the system of regular (or even better, continuous) defectoscopy monitoring of crucial aircraft structural parts. Taking into consideration increasing application of polymer composites in the aircraft, the necessity of fundamental investigations in the field of composite defectoscopy methods is of great importance. Defectoscopy of the composites is generally more difficult then defectoscopy of metal parts, therefore it is necessary to search for effective NDT methods.

2. SYSTEMS OF ULTRASONIC NDT INSPECTIONS AND VISUALISATION OF NDT RESULTS

Investigating the subject of applicability of NDT method for composite structures, the authors developed two systems for ultrasonic NDT inspections. They are based on the Panametrics 9100 ultrasonic flow detector. The first system is stationary with immersion tank (adapted for drowning the specimens in the water to obtain the acoustic coupling), and the second is mobile (US signal coupling by the stream of water). Both systems were described in the proceedings of the 3rd International Diagnostic Congress [1]. The crucial role in those systems has special software, designated for communication with the flow detector and for control of scanning operation.

A special function of this software is visualization of the defects detected in the composite structures.

Generally, the visualization process depends on analysis of analog signal from US probes, and observation the amplitude of this signal in the optionally chosen gate of the A-scan (case 1), or depends on analysis of the changes in the whole Ascan (case 2) and on generation 2 or 3-dimensional color bitmap (i.e. C-scan) resulting from probe position and signal value (or value of function based on the whole A-scan value).

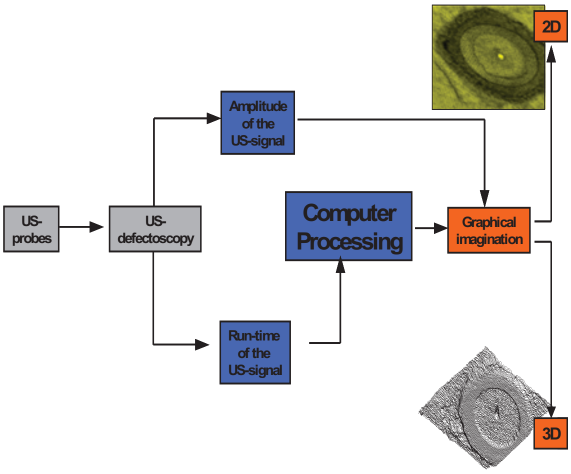

Fig. 1. Ways of flow visualization in ultrasonic defectoscopy systems

Taking into account variability of position and amplitude of the peaks on A-scans, the observation of signal in the gate established on A-scan is connected with the necessity of detection of the active part of A-scan. This gate in the majority of ultrasonic flow detectors is fixed on the A-scan windows and does not follow the movement of signal peaks. The detection of active part of A-scan has been made using differential method or gradiental method. It is possible to establish virtual gate, which follows chosen peaks (or a group of peaks) on the A-scan, and then to link the amplitude value with the color of the pixel on a C-scan.

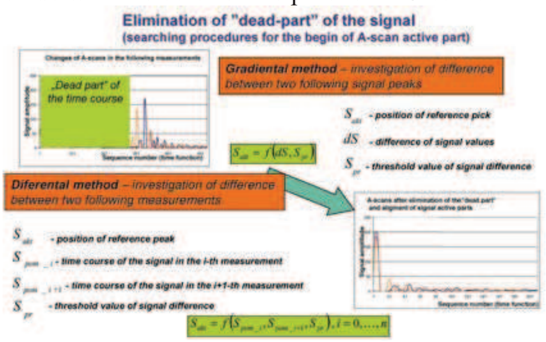

Fig. 2. Detection of active part of an A-scan

An alternative method for it is use of correlation function of the A-scans. The 1st one is so called, "template scan" taken in optionally chosen point of scanned specimen, while the 2nd signal comes from current position of the probe. The maximum value of correlation function is used then for generation of pixel color on a C-scan.

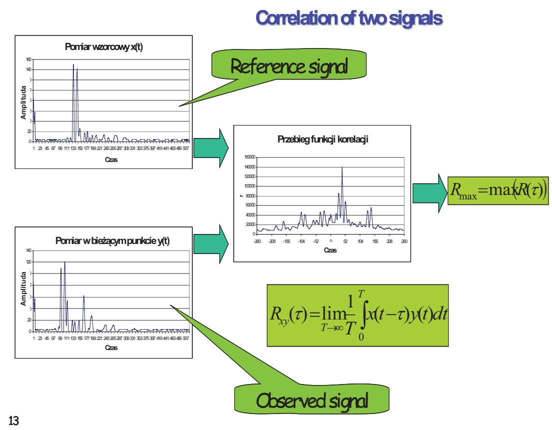

Fig. 3. Explanation of the A-scans correlation function method

In the process of elaboration of the time courses of US signals are used different methods for noise elimination and for data compression. The one of most effective method is application of the wavelet transform. The result of such transform is a set of wavelet coefficients. By eliminating from this set the lowest value coefficients and making reverse transform, it is possible to obtain smooth (unnoised) signal (similarly to the Fourier transform application). This operation facilitates detection of signal changes in consecutive measurement points.

3. APPLICATION EXAMPLES OF DEVELOPED NDT SCANING SYSTEMS

There are described below a couple examples of application of ultrasonic NDT systems, developed by the authors.

The first example concerns the specimen of composite web spar for a glider (fig. 4). Shear forces load such an element, and the critical zone in which delaminations can occur is a glue connection between the web and spar flanges. The specimen was made from the CFRP composite, and then was fixed in the special 4-joint steel frame, which enables realization of shear loads in composite shell modeling the wing spar web. This shell was subjected to low-cycle fatigue and then to a residual strength test.

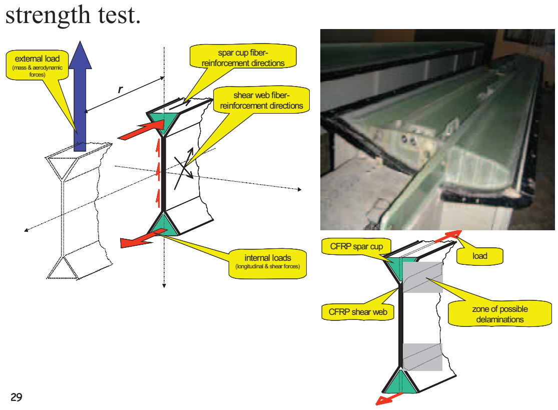

Fig. 4. The loads acting into wing spar and a critical zone in the wing spar web and flanges glue connection

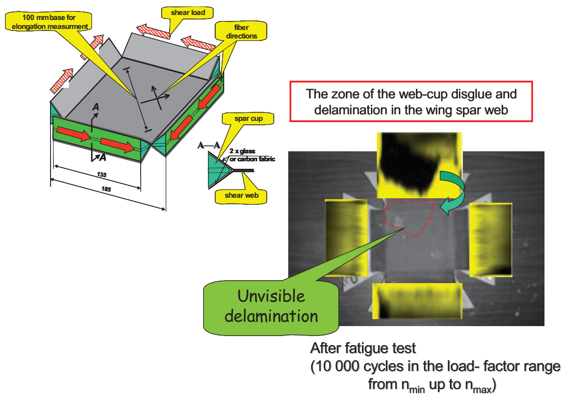

Fig. 5. Specimen modeling interaction between spar web and flanges

Ultrasonic C-scans of the web-flange interfaces after the low-cycle fatigue were shown in figure 5. It is visible, that in one interface occurs a dark area, which indicates serious delamination. This delamination was not detectable by visual inspection.

The next example concerns the specimen modeling a part of main fuselage frame, containing a special joint for wing-fuselage connection, called as a "labyrinth lock". This was a kind of joint for concentrated force implementation into thin composite shell, which was applied in the gliders build in Warsaw University of Technology. The subject of investigation was a load-bearing capacity. In figure 6 was shown a schema of specimen support and loading. The specimen was subjected into unilaterally fatigue loads (10 000 cycles of a maximum value equal 76% of a static strength). Before the fatigue test and also after each thousand of load cycles the specimen was scanned on the ultrasonic stand. In such a way a structural defect (delamination) occurring in the neighborhood of the "labyrinth lock" was monitored (see fig. 6). The residual strength test result proved that despite this delamination, the residual strength dropped slightly (although one can conjecture that the residual operational life was reduced more significantly).

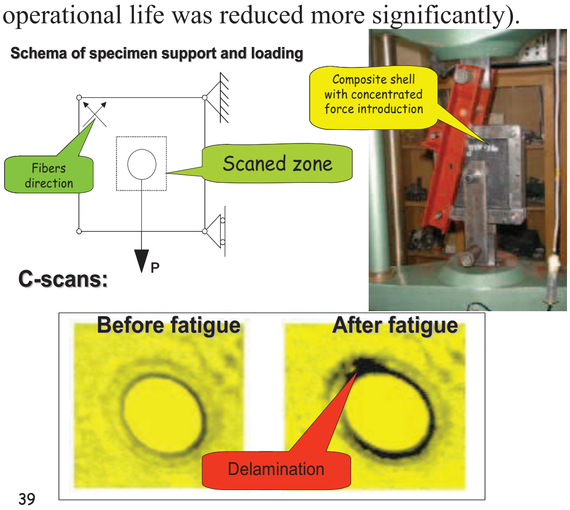

Fig. 6. Specimen with concentrated force implementation into composite shell

The next example concerns monitoring of the defects in the CFRP composite made from fibers of unidirectional orientation (as in the wing spar flanges). The specimens were subjected to impact loads with controlled energy. Some specimens were used for the so called interlayer shear load capacity test, while the rest of specimens were subjected into 1 million of fatigue loads reaching 70% of nonfatigued specimens strength. During the fatigue test the specimens were regularly scanned on the ultrasonic stand, and at the end of experiments the residual strength was examined

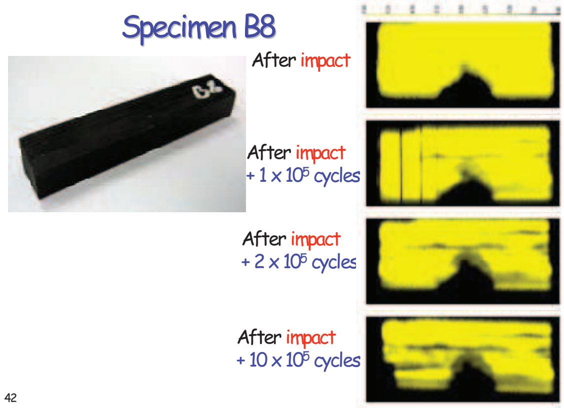

Fig. 7. C-scans of CFRP beams after impact and fatigue loads (black zone shows the defect area)

Examples presented until now show that such structural defects as delaminations or disglueing or fibers crush are easily detectable. The opposite situation occurs in case of diagnostics of a glue connection, in which the fatigue destruction runs inside the glue-layer (in a cohesive way). The example of such a situation in the glue connection between metal and CFRP composite is presented in figure 8.

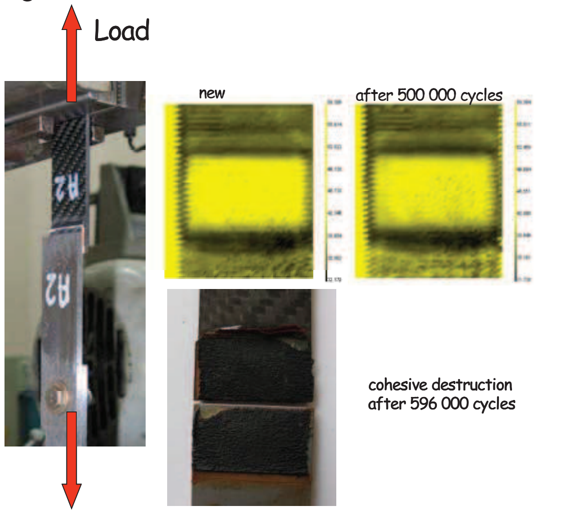

Fig. 8. Testing the glue connection *metal-composite*

On the C-scans which were made at the beginning of fatigue and just before total destruction of the glue joint any changes are not detectable. It is for the reason that in investigated case, the destruction of the glue connection occurred not by developing of disglue zone, but by micro-cracks in the whole volume of the glue layer (which was proved by later microscope inspection).

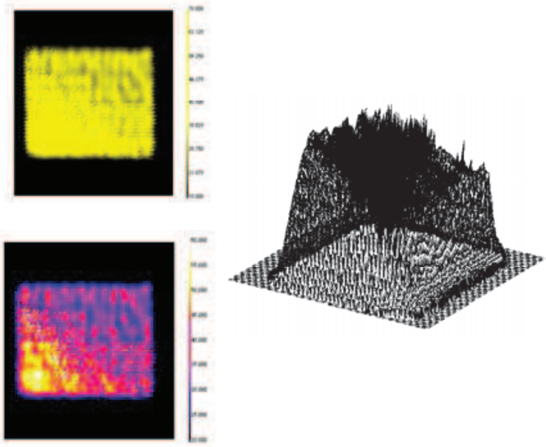

Fig. 9. Examples of different visualization methods of ultrasonic inspections of *metal-composite* glue connection

4. CONCLUSIONS

Examples presented in the paper prove high effectiveness of ultrasonic NDT methods in detection of such defects as delamination or disglueing, and partly effectiveness in the investigations of fatigue processes of the composite structure reinforced by fibers.

A low effectiveness was observed in case of investigating degradation of glue connection type *metal-composite*, which occurs in the whole volume of the glue layer in cohesive way.

LITERATURE

[1] M. Rodzewicz, G. Czerwiński: *Diagnostyka ultradźwiękowa rozwarstwień w powłokach kompozytowych*. Diagnostyka vol. 30, tom 2, 2004, str.89 – 92.

[2] G. Czerwiński, M. Rodzewicz: *Zastosowanie ultradźwięków w diagnostyce struktur kompozytowych*. 8-th International Conference „AIRCRAFT AND HELICOPTER DIAGNOSTICS" AIRDIAG'2005, Oct. 27 – 28 2005, proceedings No 5/2005.

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