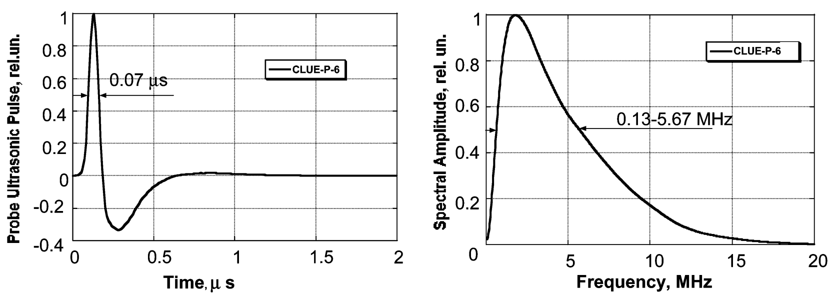
4.2.26. CONTACT LASER ULTRASONIC EVALUATION OF COMPOSITES

Karabutov A.A., International Laser Center of M.V. Lomonosov Moscow State University, Moscow, Russia;
Savateeva E.V., Institute on Laser and Information Technologies, Russian Academy of Science, Shatura, Moscow Region, Russia;
Zharinov A.N., Karabutov A.A. Jr., International Laser Center of M.V. Lomonosov Moscow State University, Moscow, Russia;
Filatov A.A., Khizhnyak S.A., Koshkin V.V., JSC "Design Bureau Sukhoi", Moscow, Russia

1. Introduction. Construction materials, such as composites, have complicated texture, that determines their mechanical properties. The size of the specific element of the texture of composite may vary in a wide range. So, it's necessary to provide wide frequency band of ultrasonic testing to investigate the composite. The traditional piezoelectric ultrasonic testing is faced with significant difficulties in solving this problem [1, 2]. To provide ultrasonic testing over wide frequency range it's reasonable to explore laser excitation of acoustic wave, which is termed as "laser ultrasonics" [3]. The disadvantage of laser ultrasonics is low efficiency of acoustic pulse excitation at free object surface, low sensitivity of ultrasonic vibration detection and hard demands to the optical quality to the object surface. It's well known, that mechanical loading of the surface irradiated by laser enhances the efficiency of acoustic pulse excitation 10-100 times [4]. The technology of ultrasonic testing using laser excitation of ultrasonic pulses and piezoelectric detection of acoustic waves with high temporal resolution is termed as "contact laser ultrasonic evaluation" (CLUE).

2. Contact Laser-Ultrasonic transducer. Contact Laser-Ultrasonic transducer utilizes laser excitation of a sharp ultrasonic pulse and piezoelectric detection of acoustic transients with high temporal resolution [5]. The duration of the excited pulse is determined by the laser pulse duration and light absorption coefficient in the OA-generator. It can vary over wide range, specified to the problem to be solved. The OA-transducer CLUE-P-6 produces an ultrasonic pulse with the duration of the order of 0.07 μs. Its temporal shape is presented in Fig. 1a. It's smooth and has sharp compression phase of 0.07 μs duration and longer rarefaction phase. The last appears due to diffraction of excited ultrasonic beam (its diameter is ~3 mm). This short probe ultrasonic signal has limited frequency band (0.13 – 5.67 MHz) at half maximum (see Fig. 1b).



(a) (b)

Fig. 1. Temporal shape (a) and spectrum (b) of a probe ultrasonic pulse of CLUE-P-6

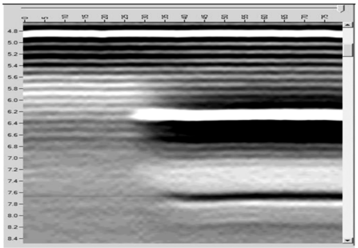


Fig. 2. CLUE image of 1-D CFRC with metal foil

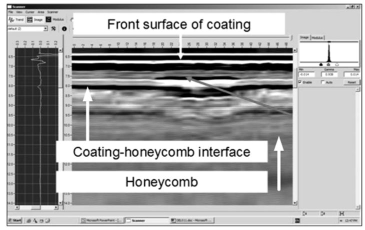


Fig. 3. CLUE image of delamination in CFRCcoating of honeycomb structure

Short duration of the probe ultrasonic pulse of CLUE provides high in-depth resolution of testing. On the other hand, ultrasonic wave (central frequency – 2.5 MHz) is affected to low attenuation in a course of propagation and provides long depth of testing. Bandwidth of the spectrum of the probe signal is two times greater, then its central frequency. This provides greater quantity of pixels in an image of a test object, then traditional ultrasonic testing. Delamination, disbanding, porosity, granulation etc. can be effectively investigated with CLUE.

3. Experimental cases. Tested sample was 1-D CFRC that has 50 μm brass foil as an artificial inclusion between 10^{th} and 11^{th} ply. B-scan of this sample with CLUis presented in Fig. 6. The upper bright line shows the reflection at the surface of the sample.

White lines below the surface correspond to the carbon layers, black lines – to the matrix layers. The thickness of the ply was 0.14 mm. So, the resolution of CLUE image is of the order of 0.1 mm for CFRC. Bright line between 10^{th} and 11^{th} ply shows the position of brass foil. The dark line below the foil shows the successive reflection of the probe pulse in the layer between the surface and the foil. As the plane of the foil is parallel to the surface, its image is sharp.

If the delamination between the plies takes place, it'll look like a dark line. B-scan of the test sample of CRFC with the delamination is presented in Fig. 3. The thickness of covering composite layer was 1.6 mm. It was attached to the honeycomb structure. The interface between them looks like dark line. The artificial delamination takes place at 1 mm depth in the covering. It's image is dark line to.

Conclusions. Contact laser ultrasonic evaluation explores short probe ultrasonic pulse. This provides enhanced in-depth resolution for limited frequency band.

The probe ultrasonic pulse of CLUE has smooth temporal shape. It provides no "dead-zone" and discrimination of soft and rigid impurities.

Small diameter of a probe CLUE ultrasonic beam provides enhanced sensitivity of small defect detection.

CLUE is reliable technique for quantitative nondestructive testing of construction materials.

References

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