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# LOSS OF QUALITY OF ULTRASONIC IMAGES AND POSSIBLE CAUSES

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**Abstract.** With the increasing use of composite materials in aviation, monitoring the quality of structures, as well as making them and using them, is become more important. Acoustic non-destructive inspection technology offers a promising way of monitoring, tracking and inspecting the quality of those materials. The article deals with loss of ultrasonic image quality and possible causes.

**Key words:** Composite materials, ultrasonic waves, ultrasonic image quality problems.

## 1. Introduction

In order to extract the maximum benefit from ultrasonic equipment for the non-destructive monitoring of aircraft structures (Приборы …1986) and to make full use of its diagnostic potential, it is necessary to be aware of the limitations inherent in ultrasonic scanning as a method (Кайно 1990; Kopūstinskas 2002). In addition, it is important not to forget about possible changes in the quality of ultrasonic images and characteristic image artefacts that may cause the distortion of ultrasonic images Diagnosis made on the basis of such images may have incorrect results. Some of the most common causes of loss of ultrasonic image quality are examined below.

## 2. Electronic equipment

A significant amount of image artefacts can occur in electronic devices that produce electrical pulses, as well as those that receive acoustic signals and process them, triggering the generation of acoustic signals. Since most of these artefacts can be easily identified, we will look at only the most significant of them that occur in normally functioning ultrasonic hardware, and as well as the inevitable limitations and performance trade-offs.

**Stray artefacts.** The most natural source for false echo signals in electronic devices is own noise. This factor limits the use of quality equipment at a low-level signal. The signal-to-noise ratio expresses the relationship

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between diagnostically useful echo-signal amplitude components of noise:

$$t_{sv.n\max} = \frac{r_f}{c}\left[1 - \sqrt{1 + \frac{x_n^2}{r_f^2} - 2\frac{x_n}{r_f}\left(\sin\gamma_0 - \sin\gamma\right)}\right]. \qquad (1)$$

For useful information recognition, the ultrasonic image signal-to-noise ratio level must be equal to or greater than 3 dB (1.4 times) at any point.

**Recovery time.** The recovery time of an echo-signal receiver may limit the diagnostic possibilities of the equipment, suppressing echo signals coming from the beam sampler ultrasound study area. The amplitude of the internal electrical pulse that generates impulses for the electro acoustic transducer is much higher than the expected amplitude of the echo-signal response. To avoid internal signal reflection, the receiver amplifier is blocked for some time after the emitted pulse and cannot receive or enhance the first reflected echo signals from the object being studied. It is clear that blocked signals are from near the study area. The time required for the normal operating mode to return to normal settings is called recovery time. Testing of composite structures requires this time to be minimal.

**Range setting restrictions.** Using ultrasonic defectoscope equipment close to the ideal, the largest distance $a_u$ from the ultrasonic transducer at which signals still occur and can be visualized is equal to half the distance that the ultrasound waves passes until new ordinary acoustic impulse are sent and the distance measuring system returns to primary state. This distance is coupled with a working ultrasonic frequency and can be determined by this formula:

$$a_u = \frac{c}{2\times f_g}, \qquad (2)$$

where $c$ is ultrasonic propagation speed in the environment being studied.

## 3. Ultrasound converter selection

**Measuring ability resolution.** The effective diameter of an ultrasonic beam depends primarily on the dimensions of the sending ultrasonic piezo element and wavelength in respect to the environment being studied. Receiver gain of TAP influences the effective width of the ultrasound beam, causing, for example, at very low amplifying levels, only signals with large amplitudes to be detected and low amplitude components to be lost. Transverse measuring ability (also known as scanning resolution) of ultrasonic converter is illustrated in figures 1 and 2.

**Directional characteristics of lateral leaflets.** All ultrasonic converters, especially those with short wavelength $\lambda$, has additional sideslip compared to the environment being studied. This phenomenon causes parasitic, or so-called phantom, echo signals, but with the use of pulse mode for analysis, the phantom echo effect is avoided.

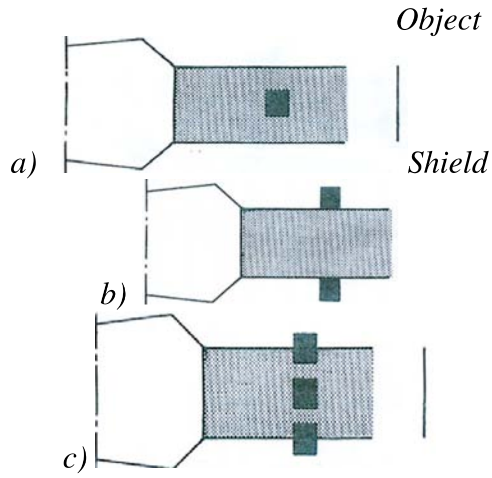



**Fig 1.** Simplified illustration of measuring ability:
a – maximum resolution of measuring ability; b – limit of the resolution of measuring ability; c – unexamined object

**Fig 2.** Ultrasonic converter used for examination of bonded materials and adapted for each test case, type of investigation, and target configuration

**The inner echo-reflection.** A poorly designed or badly constructed ultrasonic converter can generate an unacceptably large number of false reflections having really nothing to do with the structure of the object being studied and may complicate the process of examining the object.

There may be several reasons for these unwanted internal reflections to appear in converter. Lack of a quality housing cover, sound insulation, and absorption properties can cause phantom reflections that are displayed on a defectoscope screen and may look as if they are located in the field of research. Not precisely coordinated piezo and the outer surface acoustic impedances can cause problems with the quality of transmission and reception of the signal and the appearance of false reflections.

## 4. Spatial geometric distortions and ultrasonic speed fluctuations

Ultrasonic speed fluctuations in composite materials are generally not high. Changes in speed occur within the composite materials and aviation structural fasteners, which can be made, for example, from metal. A sudden increase in ultrasonic speed caused by the consequence of its effect is that the structure of the object being investigated, which is located in the 'high-speed items', will appear on the screen as if it is located closer to the ultrasonic converter than it is in reality. It may also occur, so-called angular deflections when the ultrasonic beam is not vertical to inserts with higher ultrasound speeds and beam changes its angle while passing them. In this case, the line between ultrasonic converter axis and the investigated object will no longer be a straight line (Fig 3b). It is very important to understand that while studying the aerial structures of composite materials.

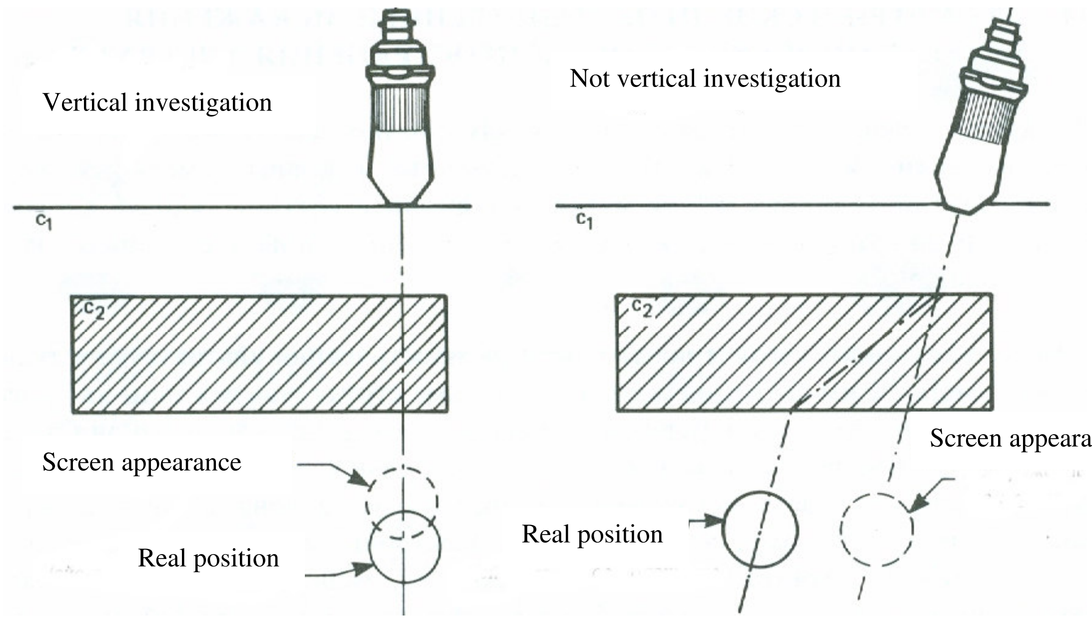
Figure 4 demonstrates a similar model of the distortion of the ultrasound image, when the specimen has defects filled with liquid, for example, water spots, performing a sort of acoustic lens function and causing unwanted ultrasound beam breakage, as in the example.

## 5. Fake reflections

Fake reflections can occur because of a poorly constructed ultrasonic changer or one that has been damaged in some way. Such things occur infrequently, however, because quality control and the technical certification of an ultrasound scanning apparatus, as a rule, are carried out with sufficient care.

Most of the false reflections occur within the specimen as re-reflections between boundaries with strong reflectance characteristics (Fig 5).

Other causes of multiple reflections are characteristic of the same material structural inequalities in the material (grain), who causes these false (*in terms of the defectoscope)* structural reflections.




a b

**Fig 3.** Basic geometric distortions caused by ultrasonic speed changes in the test area

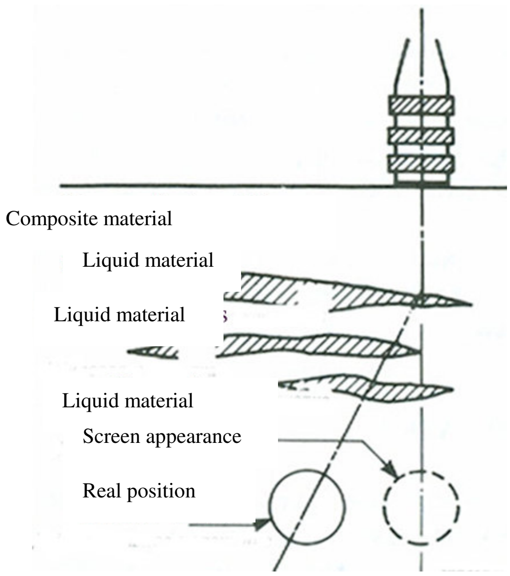



**Fig 4.** Conceptual representation of ultrasound beam breakage in investigated material, which has a defects filled with liquid, performing a sort of acoustic lens function

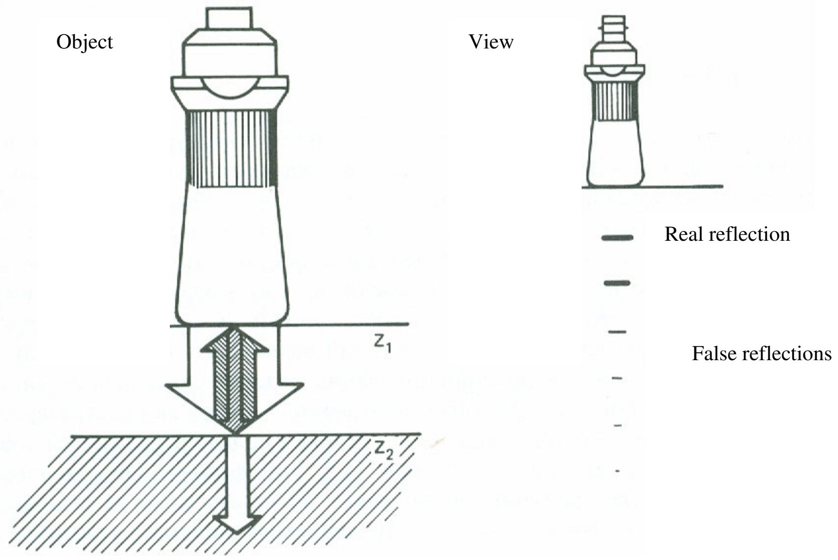



**Fig 5.** Re-reflections on strong reflecting materials in area being studied

## 6. Grainy image

Ultrasonic image is often encountered the phenomenon of grainy image when using concentrated and precisely directed beams to the reference object. In practice, this means that the examination of structurally non-homogeneous materials includes reflections of ultrasonic three-dimensional structural interference, causing ultrasonic image graininess (Fig 6).


**Fig 6.** A typical grainy image of composite material with structural defects in the upper parts of the image on the right, recognisable by the change in the structure and acoustic shadow below the defect

Determination of defects in composite materials and other objects manufactured from such materials in aviation structures necessitates not only the usual defectoscope organoleptic defect detection techniques (Кайно 1990) but also the newly developed ultrasound spectral imaging and statistical characteristics (Ness *et al.* 1996, Pileckas 2004).

## 7. Conclusions

The paper presents specific deviations of ultrasonic images that occur in the study of non-destructive materials. The causes of such artefacts and ways to avoid them are explained.

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**ELEKTROAKUSTINIŲ GARDELIŲ DINAMINIS FOKUSAVIMAS KOMPOZITINIŲ MEDŽIAGŲ DEFEKTOSKOPIJOJE**

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S a n t r a u k a

Vis plačiau naudojant kompozitines medžiagas aviacijoje aktualėja ir jų kokybės būsenos stebėjimas konstrukcijų gamybos ir eksploatacijos metu. Akustinės neardomosios kontrolės technologijos atveria, mūsų nuomone, perspektyvias kompozitinių medžiagų charakteristikų bei jų parametrų stebėjimo ir tyrimo galimybes. Straipsnyje nagrinėjamas priimtinas kompozitinių medžiagų tyrimui akustinių vaizdų formavimo būdas, panaudojant akustinės antenų gardelės dinaminį spindulio fokusavimo būdą.

**Reikšminiai žodžiai:** kompozitinės medžiagos, ultragarso bangos, antenų gardelės akustinio „spindulio“ dinaminis fokusavimas.