High Frequency Ultrasonic Systems with Frequency Ranges of 35 to 200 MHz

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Abstract. High-frequency ultrasonic systems (HFUS) deliver high resolution because of the short wavelength and short pulse widths. The applications are restricted to thin components and/or materials with low sound attenuation. The investigations are usually carried out in immersion technique. Our new “local immersion technique” with new transducer adapters enables also in-field inspections with an extreme high resolution. For this application the MUSE (Mobile UltraSonic Equipment) is used. The scanning speed is increased to 1 m/s.

For different applications we can deliver systems like USPC 3010 HF with a bandwidth of 35 MHz, USPC 3010 VHF with 65 MHz and UCPC 3060 UHF with 200 MHz. The external pulser/receiver unit enables a short cable to the transducer. This is a requirement for an optimal pulse shape and a high signal- to noise ratio. Different imaging systems and their applications will be presented.

Introduction

High frequencies in a range of 20 to 200 MHz generate in dependence of the velocity a wavelength between 25 a 500 µm in the material. Therefore very small defects can be detected. The possible extremely short pulses provide a high axial resolution.

Our company Dr. Hillger founded in 1984 develops special ultrasonic imaging systems. Since 1990 we are involved in high-frequency ultrasonic testing with a large dynamic range and high resolution. Our system HFUS 2000 provided a bandwidth of 120 MHz [1]. Our new systems enable a bandwidth up to 200 MHz.

In order to have a short cable to the transducer the pulser/receiver is built-in a separate case which is situated directly on the scanner near the transducer. Transducer with different impedances can be used and deliver a high signal-to noise ratio. The other components of the system are the scanner with water tank and a 19"-rack with a scanner controller and a computer.
1. High-Frequency Systems

1.1 Overview

The USPC 30XX imaging systems are of modular design and consist of a scanning unit with pulser/receiver box, a rack with CNC-controller, the Ultrasonic system USPC 30XX and the software Hillgus. The external pulser/receiver is selected for different applications and therefore for different frequency ranges. The pulser/receivers Hill-Scan 3010 HF, Hill-Scan 3010 VHF and the Hill-Scan 3060 UHF are highlighted by an avalanche pulser. In opposite to a standard MOS pulser this kind of pulser delivers the highest possible bandwidth thanks to the avalanche effect [2-5].

The upper cut-off-frequency of the receiver must be much larger than the transducer frequency. The nominal frequency of the transducer is in most cases the centre frequency. In order to get short pulses the bandwidth can be 100 % of the centre frequency so that the receiver has to transmit 50% higher frequencies of the transducer frequency. That means that a broadband 15 MHz (nominal frequency) transducer requires in minimum a 25 MHz pulser/receiver. An example presents Fig. 1, in which an A-scan of a glass-plate reflector and a FFT recorded with a 15 MHz transducer are shown. The bandwidth of this transducer reaches even 19.1 MHz -6 dB (4.6 to 23.7 MHz).

Tab.1 lists the different USPC systems for high-frequency testing and their technical data. A hardware signal conditioning is used in all cases with high- and low-pass filters or with band pass filters. Additionally our software Hillgus provides software filters and - gain setting in 0.1 dB steps so that and exact system setting is possible for highest signal to noise ratio and highest resolution. All systems consist of our Software Hillgus and of a scanner so that a turn-key system is given.

![A-scan and FFT](image)

Fig.1. A-scan and FFT of a 15 MHz transducer
### Table 1. HF systems

<table>
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<tr>
<th>System</th>
<th>Frequency range</th>
<th>Signal condition</th>
<th>Highlights</th>
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<tr>
<td>USPC 3010 HF</td>
<td>&lt; 0.01 to 35 MHz</td>
<td>High-pass filters: 0, 1.0; 2.0; 5.5 MHz&lt;br&gt;Low-pass filters: 3.0; 6.0; 11.0; 35 MHz</td>
<td>High-frequency ultrasonic testing of composites P/R deliverable as external box or as PC board</td>
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<tr>
<td>USPC 3010 VHF</td>
<td>&lt; 0.01 to 65 MHz</td>
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<td>USPC 3060 UHF</td>
<td>&lt; 0.01 to 200 MHz</td>
<td>Band pass-filters with centre frequencies: 10; 15; 25; 35; 50; 80 and 100 MHz, Broadband: &lt;0.01 to 200 MHz -3dB</td>
<td>Inspection of bondings in relay contacts Thickness measurements in thin parts Transducer characterizations P/R only in an external box</td>
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### 1.2 Scanning systems

In order to provide high resolution in-field ultrasonic inspections the MUSE (Mobile Ultra-Sonic Equipment) has been developed. The Muse Z 400 is a light weight scanner with a mass lower than 6 kg and attached to the component with vacuum pads. This system can be used for vertical attachment and overhead. Curved surfaces of the component do not cause any problems. The system shown in Fig. 2 consists of a motor-driven manipulation system, a water circulation system for the coupling and the PC-board based ultrasonic system USPC up to 65 MHz built in a portable computer [2].

![Fig. 2. MUSE scanner with water box and ultrasonic system.](image)

The scanner data are: 434 mm x 275 mm area, up to 40 µm resolution and up to 1000 mm/s scanning speed. The coupling technique developed for the MUSE (local immersion technique) provides the application of focused transducers without problems (air bubbles do not affect the testing) so that a high resolution is also available for field inspections. The improved adapters for transducers up to 50 MHz include an adjustable internal water delay for different focal distances. This local immersion...
technique is also useful for laboratory investigations because no water tanks are required and the test components stay nearly dry.

Our ImmersionScan, a special scanner for plate testing in immersion technique provides the advantage that air-bubbles can be easily seen and eliminated (Fig. 3) [6]. The scanning area of 1000x500 mm enables the testing of larger plates with a scanning speed up to 300 mm/s and a resolution of 12.5 µm. Fig. 4 shows an industrial scanning system with enclosure (dust protection). The scanning area is 500x500 mm with a resolution of 12.5 µm.

1.3 Software Hillgus and Oculus

Our software Hillgus is easy to handle and provides all setting for manipulation systems and ultrasonic pulser/receivers and an automatic (full-wave) data recording and imaging with A-, B-, Bt-, C-, D- and F-scans. Oculus is a powerful scan viewer with many evaluation and filtering features including and automated defect area measurement. Special evaluating tools are available for automatic defect areas, and percentage bonded or debonded areas.

2. Applications

Fig. 5 presents a B-scan of a monolithic CFRP specimen (DLR-FA, Braunschweig, Germany) with multi-directional lay-up and a thickness of 2 mm. The different layers are clearly indicated, exactly the interfaces between them. The impact causes different delaminations in different depth indicated by black lines (like a “Christmas tree” in depth). The high resolution delivers the USPC 3010 HF with a 50 MHz foil transducer.

Fig. 6 shows a B-scan of a CFRP-component with porosities which are displayed by short double lines- Also the layers are indicated, this is because of the large bandwidth of a 5 MHz transducer excited by an avalanche pulser. The different distances of the backwall echo (double yellow
lines) to the interface echo indicate different component thicknesses. The position of the stringer is shown by a step of the backwall echo. Fig. 7, a C-scan of the backwall echo of a CFRP laminate with a thickness of about 4 mm presents the indication of pores. The echo dynamic curve (Fig. 8) indicates a sharp amplitude decrease of 30 dB.

![Fig. 5. B-Scan of a CFRP laminate, indication of layers and delaminations](image1)

![Fig. 6. B-Scan of a CFRP laminate, indication of layers, porosities and backwall echo](image2)

![Fig. 7. C-Scan of a CFRP laminate, indication porosities](image3)

![Fig. 8. Amplitude profile at y= 140 in Fig. 6.](image4)

The echo trace of a 0.1 mm thick razor blade received with a 100 MHz transducer is given in Fig. 9. This result in direct coupling shows a different pulse response with increasing number of the backwall echo.

The dark red areas in the C-scan (Fig. 10) mark the debonded areas of a relays contact. Depending on the size more than 100 pieces can be tested in one C-scan recording. The perceptually values of the debonded areas and other parameters can be evaluated automatically with our Oculus-software.
High frequency ultrasonic testing enables the quality control of 0.3 mm thin steel plates. Fig. 11 presents a C-scan of the backwall echo of such a component. Because of the short time of flight in the material (56 ns) and the slightly curved component an exactly interface triggering was necessary in order to position the gate for backwall echo. An amplitude profile (Fig. 12) shows variations of 40% of the amplitude.

Even flat bottom bore holes with a diameter of 50 µm can be detected (Fig. 13). The C-scan (a) with a scanning grid of 50 µm shows the yellow marked area with the bore hole. The amplitude profile (b) at the flat bottom hole shows an increase of 6 dB above noise. The A-scan (c) clearly indicates the echo from the hole at 11.85 µs.
4. Conclusions

High-frequency ultrasonic systems deliver high resolution because of the short wavelength in the material and the short pulse width thanks to a large bandwidth. Note that the sound attenuation is frequency-depending so that high frequencies can only penetrate small thicknesses. The maximum pulse frequency is decreased during propagation through the material too. The water path of coupling have to be as short as possible in order to have less sound damping before reaching the test specimen. The avalanche transmitter is a requirement for high frequency inspection. It provides the broadest possible excitation signal. Optimizations of pulse parameters can be carried out by receiver filters and by software IIR filters. This combination delivers the highest signal to noise ratio and best testing results.

References


