QuintSonic 7

Thickness measurement of paint coatings applied on plastics, wood and metals according to the ultrasonic measuring principle

Coating Thickness Measurement

In the finishing industry, a great number of various protective coatings are used to protect a product from corrosion or other influences. For all application **it is vital to know the thickness of a coating and/or the weight per unit area** as the properties of a coating depend on this variable.

The quality of a coating determines

- corrosion protection and protection from wear-and-tear
- hardness
- specific electrical resistance
- other physical or chemical properties of a product.

Principles used for Coating Thickness Measurement

Basically, the principles can be divided into

- **destructive** and
- **non-destructive** methods.

For continuous measurement or measurement during the production process, only non-destructive methods can be applied.

In coating thickness measurement, the most commonly used methods are the eddy currents- or magnetic principles. Both are electromagnetism based methods.

Magnetic induction principle (DIN EN ISO 2178:1995)

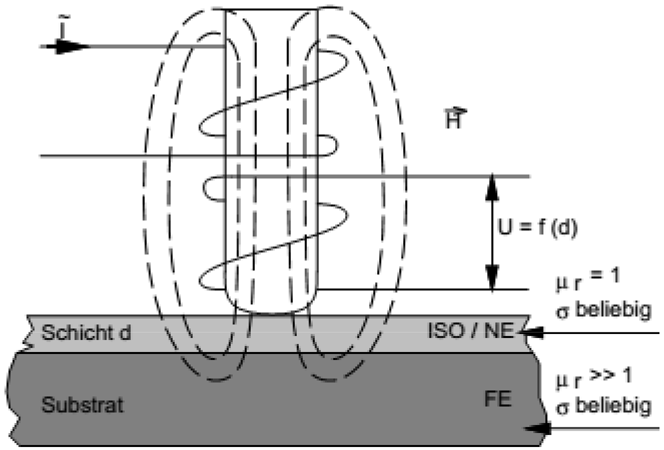
This non-destructive method is suitable for nonmagnetic coatings (such as zinc, chrome, paints, enamel, plastics, rubber etc.) applied on ferromagnetic substrates (ferrous bases and steel).

Eddy-currents principle (DIN EN ISO 2360:2004-04)

This non-destructive method is suitable for electrically non-conducting coatings (paint, plastics, ceramic, anodising, phosphate coatings, etc.) applied on non-ferromagnetic metals (aluminium, magnesium, cupper, brass etc. or on austenitic steel).

Electromagnetic Principles

Once you place the sensor onto a coated metal object, the measuring signal will change as a function of the distance between sensor and substrate. The distance equals the coating thickness.



This methods, however, are NOT suitable for paint coatings on non-metal substrates such as plastics, wood or glass.

Ultrasonic Coating Thickness Measurement – Field of Application. Some Examples:

... on plastics:	single and multi-layer coatings in the automotive industry (car bodies, bumpers, fittings or components)
... on metal:	in the car body manufacture for measuring primers, base coat and clear varnish.
... on wood:	in the forest industry for measuring decorative paint, sealant or protective varnish on all wood substrates or medium-density fibreboards such as furniture, parquet flooring, etc.

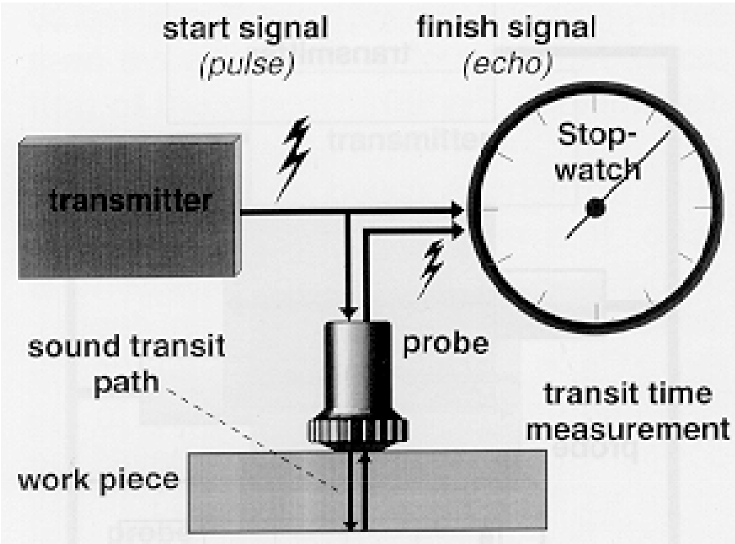
No other non-destructive method (eddy currents or magnetic induction) is able to measure such settings of task. The ultrasonic method provides a solution to any of the above applications.

Ultrasonic coating thickness measurement -
New measuring capabilities thanks to the innovative technology!

Sound Waves - The Pulse-Echo Method

Basic requirements for ultrasonic material testing

- good sound conductivity in solids
- sound reflection at the interfaces (material flaws, boundary layers)
- frequency range: approx. 0.5 MHz to 80 MHz



$$d = c * t/2$$

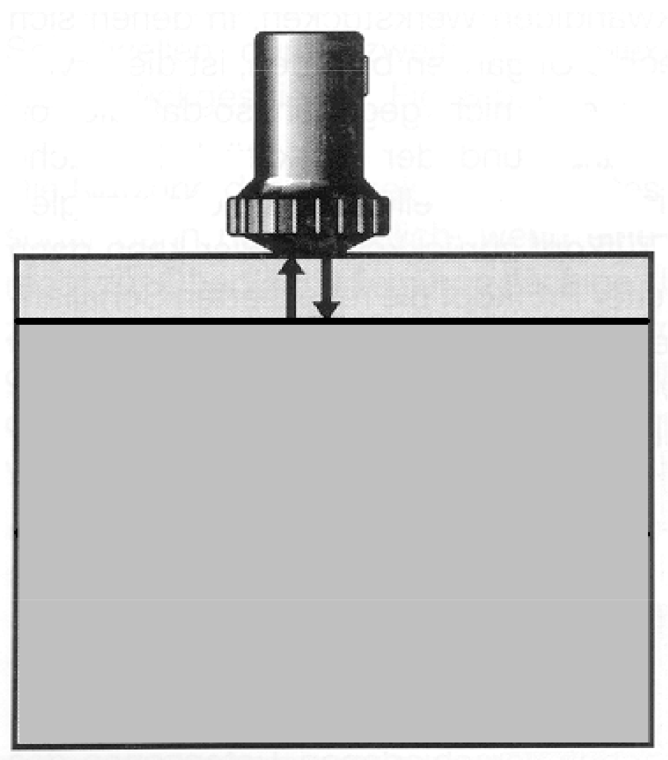
d = sound path in µm (mm)
c = sound velocity in m/s
c depends on the material!
t = travel time of sound in ns (µs)

The time interval required by the sound to travel through a layer and to be reflected back can be used as a measure to determine the coating or wall thickness

Sound Waves – Pulse-Echo Method - Example Calculation

Coating

Base



Calculation of sound travel time for a paint coating of 10 µm thickness

(c = 2375 m/s)

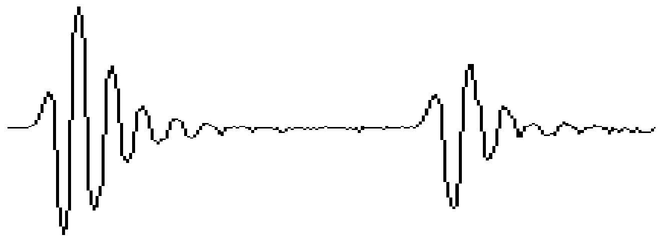
d = c * t / 2   ===>   t = 2 * d / c

t = 2 * 10 µm / 2.375 m/s

t = 8.421 ns

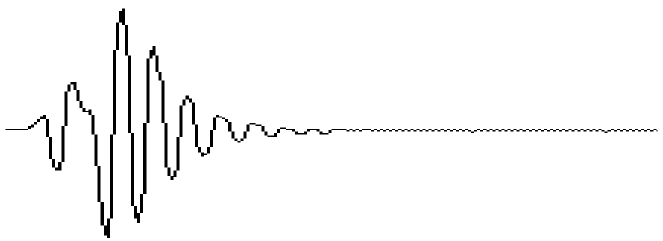
Limitations to the Conventional Pulse-Echo Method

Echo signals from polystyrene layers of different thicknesses
(ultrasonic probe CLF 4, 15 MHz)



1 mm layer thickness, 850 ns (travel time of sound)

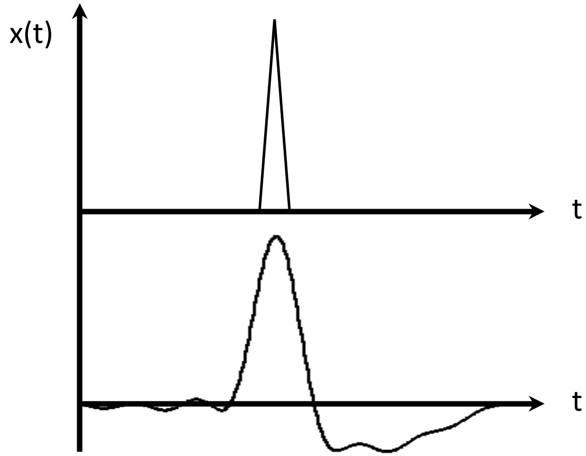
0.1 mm layer thickness, 85 ns (travel time of sound)



0.01 mm, 8,5 ns (travel time of sound)

Due to the probe's oscillation time of 150 ns (corresponding to 150 µm coating thickness), the echo pulses in very thin coatings cannot be separated any more.

Ultrasonic Coating Thickness Probe QS7
Increasing Resolution through Pulse Shaping of the Interface Echo



Theoretical pulse shape

Measured pulse shape, width 25 ns

- Active wide-band 50 MHz PVDF probe
- Sudden transducer excitation (short pulses, large bandwidth)
- Use of PVDF (polyvenylidine flouride) as transducer material
- Strong and adapted damping of transducer backside
- Digital sensor-integrated signal processing. With this technique, any required measuring signal is created and processed solely in the sensor.
- Measurement is triggered by pressing the spring mounted probe housing

Ultrasonic Coating Thickenss probe QS7
Increasing Resolution through Pulse Shaping

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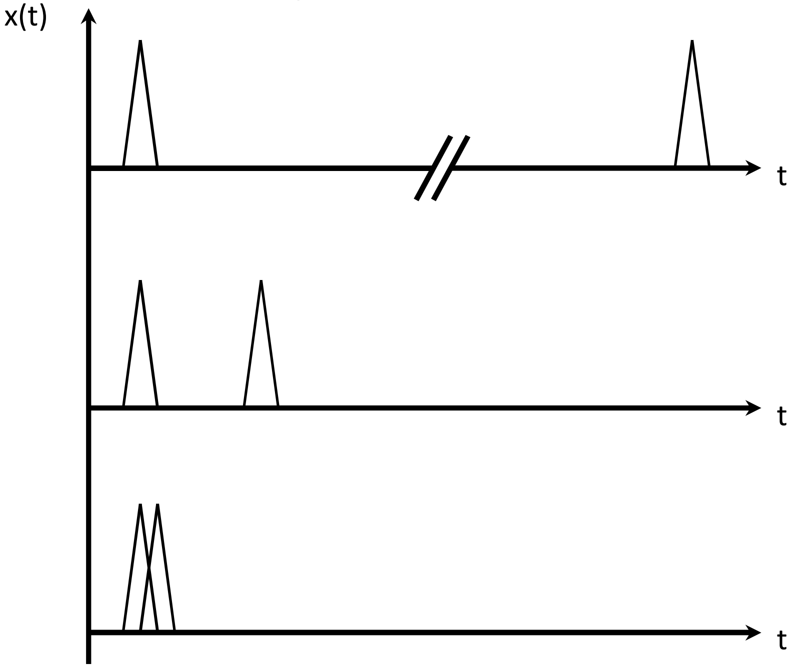


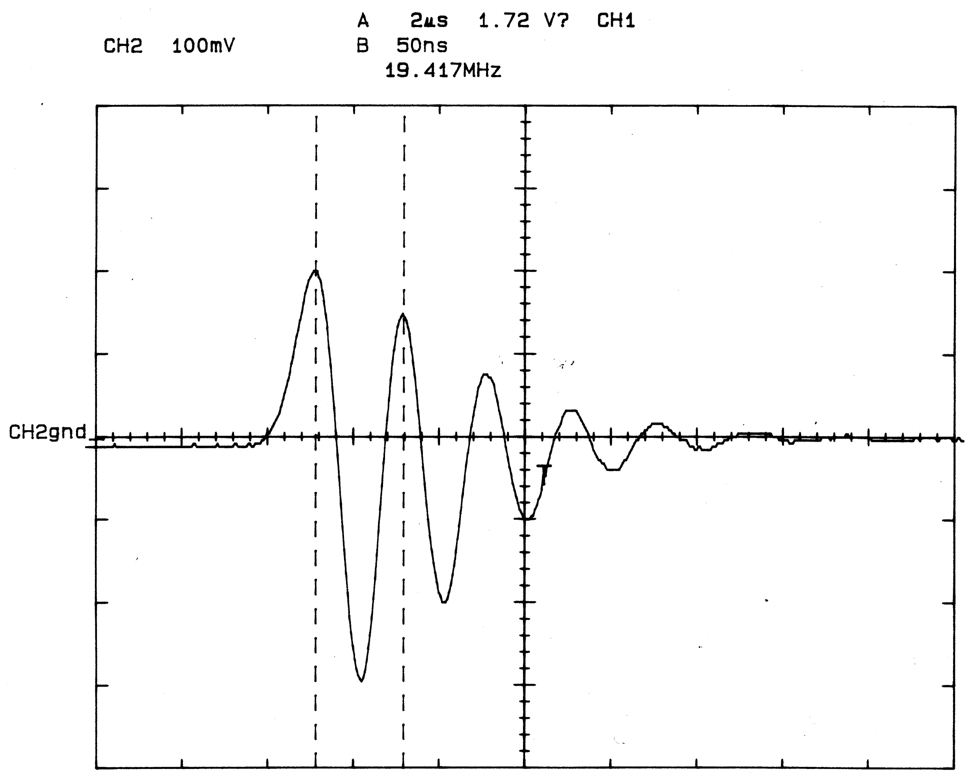
1 mm layer thickness, 850 ns (travel time of sound)

0.1 mm layer thickness, 85 ns (travel time of sound)

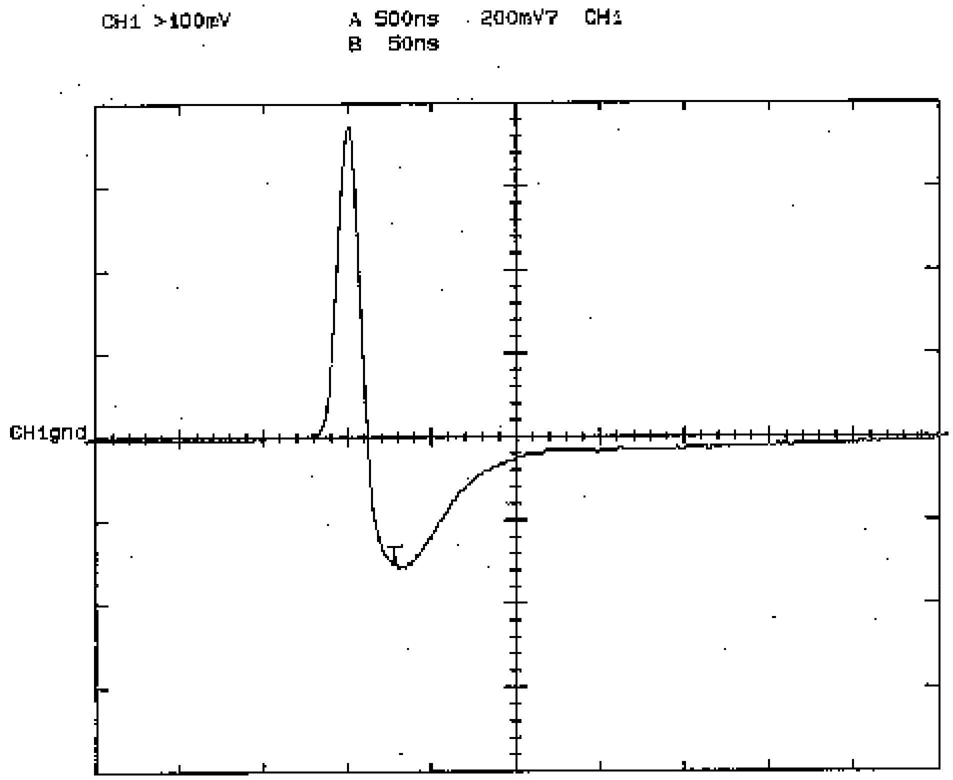
0.01 mm, 8,5 ns (travel time of sound)

Pulse shaping clearly improves separation of echo signals reflected from thin layers.

Ultrasonic Coating Thickness Probe QS7
Comparison of Echo Ranges



Wall thickness probe CLF 4



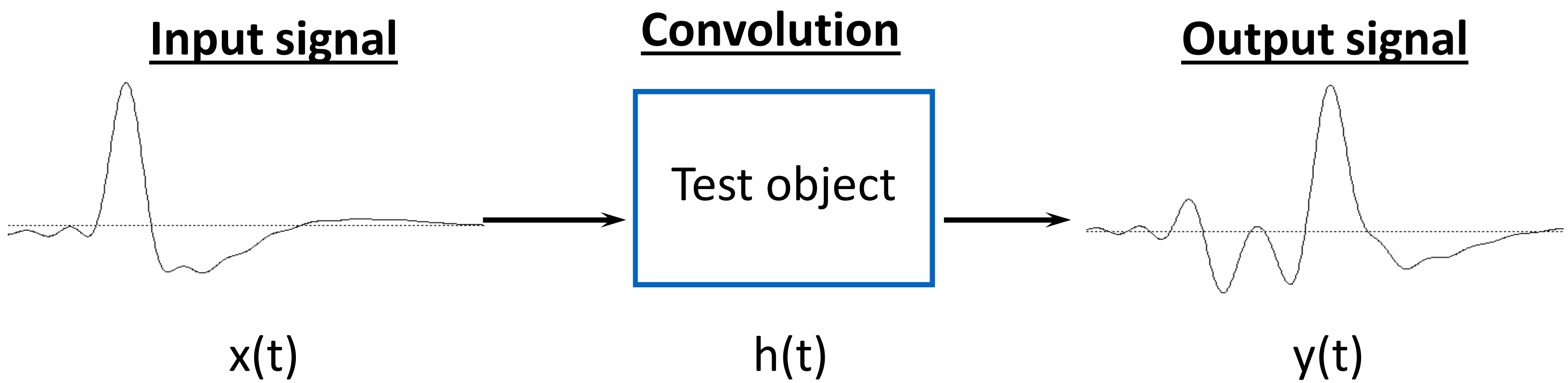
Coating thickness probe QS7

Convolution Principle
Increasing Resolution through Signal Processing

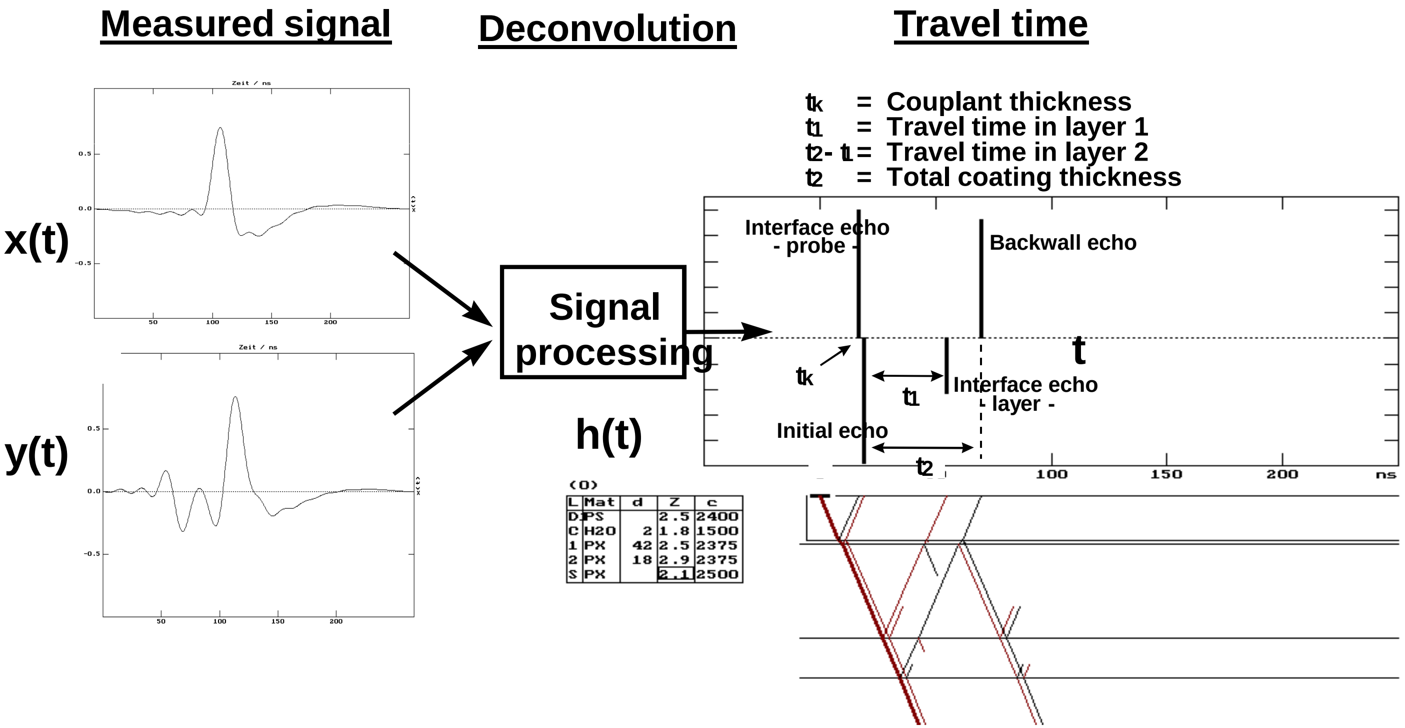
Principle of operation:

When passing through an object, the ultrasonic pulse changes according to the reflection and transfer characteristics of the material to be tested. This change is referred to as "convolution" (mathematical symbol: *).

y(t) = Measured signal (when the probe is coupled to the object)
x(t) = Measured reference signal (probe held into the air)
h(t) = System response (function to be searched)



Deconvolution Principle
Increasing Resolution through Signal Processing



If the echo reference signal x(t) and the measured signal y(t) are known, a mathematical algorithm can be used to reverse convolution (deconvolution) so as to give the system response h(t). From this response, conclusions can be made on the test object characteristics enabling you to determine the travel times of each layer. The travel times can be used as a measure for coating thickness.

Advantages of the deconvolution method:

- Even sound travel times shorter than the initial pulse duration can be measured.
- Minimum measurable coating thickness: 10 µm
- Also ultrasonic patterns without any visible interface echoes can be evaluated.
- Separation of several layers in only one measuring operation.

Limitations to the Method
Requirements for optimal Coating Thickness Measurement

As a prerequisite for reliable testing, the acoustic impedance values of the substrate material and the individual coating layers need to vary sufficiently to ensure the sound will reflect from the layer interfaces. Due to the limitations given by the physical conditions, the use of the QuintSonic probe is restricted accordingly.

$Z = \rho * c$

Z = acoustic impendance
ρ = density (Rho)
c = sound velocity

→ $^{Z1}/_{Z2}$ Z1 should vary from Z2 by at least 5 %

In most cases, a 5% variation in impedance values is given. That's why even very similar impedance values of polymers can be separated acoustically so that you can separate the different layers of of a layer system in one measuring operation.

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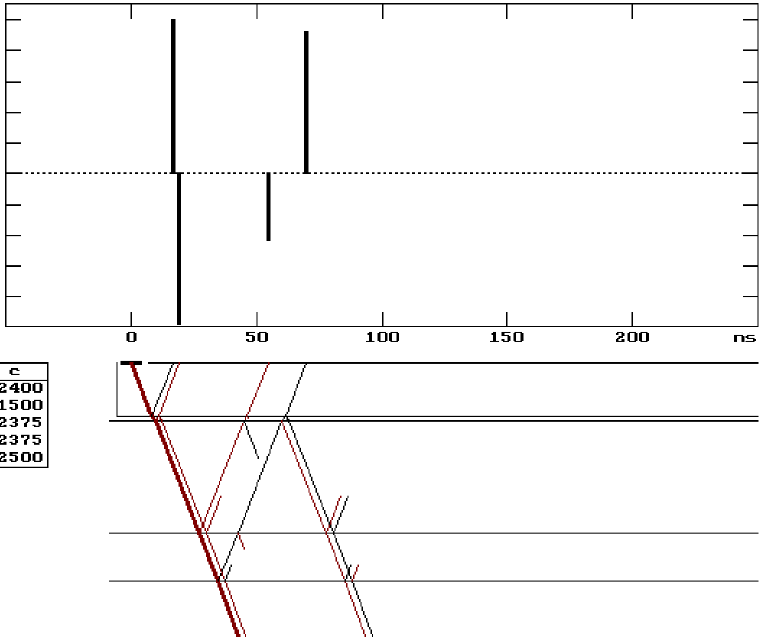
Limitations to the Method
Examples by using the Layer Model

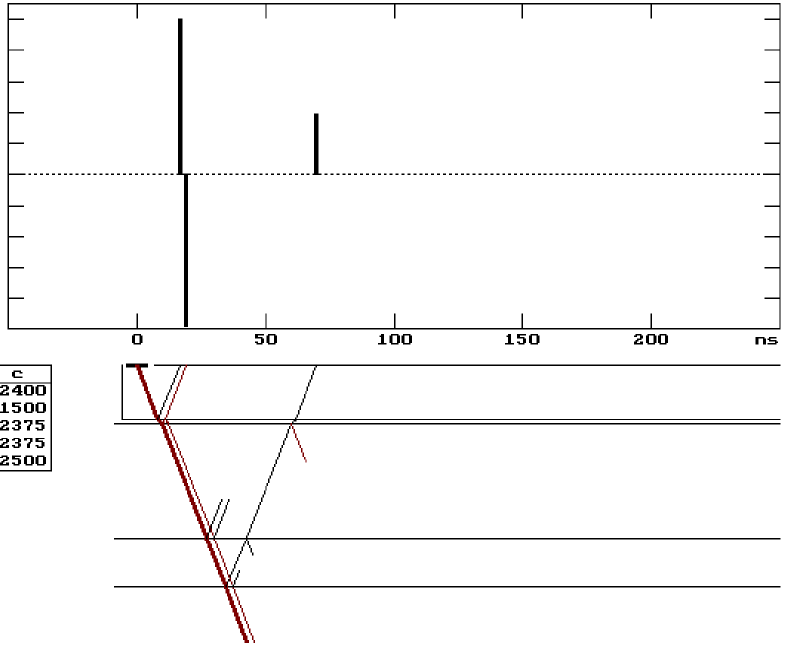
Two-layer paint coating on a plastic base



(0)

L	Mat	d	Z	c
D	PS		2.5	2400
C	H2O	2	1.8	1500
1	PX	42	2.5	2375
2	PX	18	2.9	2375
S	PX		2.1	2500

successful measurement



(0)

L	Mat	d	Z	c
D	PS		2.5	2400
C	H2O	2	1.8	1500
1	PX	42	2.5	2375
2	PX	18	2.4	2375
S	PX		2.1	2500

It is not possible to evaluate the first layer as the variation in impedance values is not sufficiently good.

Measuring Procedure

- For processing the ultrasonic receive signal, a valid reference signal is required.

- For ultrasonic measurement, the use of a couplant is required. This is to ensure a good contact between probe head and measuring object. The couplant enables a transfer from the generated ultrasonic wave into and out of the measuring object. The main target is to couple in and out (receive signal) a maximum amount of energy.

- Make sure the couplant exhibits the required acoustic properties.

Coupling agents

Using air as a couplant is completely unsuitable and will provide no results. Even if you firmly press the sensor onto the measuring object, a small air gap will remain. For that reason, using air as a couplant is not possible.

The following types of couplants are appropriate for measurement:

- clean water (preferably distilled water)
- clycerin
- coupling gel

How to take Readings

- Use an appropriate amount of couplant and spread evenly over the measuring spot. When using water, a one large drop will be sufficient.

- Hold the probe at the grey spring-loaded sleeve.

- Put the probe vertically onto the measuring object. Push down the grey probe sleeve to the stop.

- Measurement will launch and the calculation of coating thickness (thicknesses) will be made automatically. This procedure will take around one second.

Calibration

In ultrasonic measurement, the primary measured variables are the differences in travel times between the various portions of the transmit and receive signals.
In coating thickness measurement, such travel time differences range around a few to several hundred nanoseconds (billionth of a second).

The probe refers to a crystal-time base with a typical accuracy of around ±50 parts per million (±0.005%).

For that reason, it is not necessary to calibrate the measuring system.

Calibrate for the sound velocity

One decisive factor of influence results from the measuring object itself: the sound velocity. In ultrasonic measurement, you have to calibrate for this parameter.

When converting the differences of travel times you have measured into coating thickness, the sound velocities in the individual layers act as constants of proportionality. These variables are properties of the measuring object and vary according to the material to be measured. Most times, they are determined by an optical evaluation of a material cross section. Once determined, the variables can be made available to the measuring system in the form of a sound velocity calibration

This explains why a sound velocity calibration is vital for the accuracy of an ultrasonic coating thickness gauge.

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How to calibrate QuintSonic 7

QuintSonic 7 offers several methods for a sound velocity calibration.

•Enter numerical values for the sound velocities

The numerical values of the sound velocities must be known for each individual layer.

•Using reference tables
- Literature table
- User-table

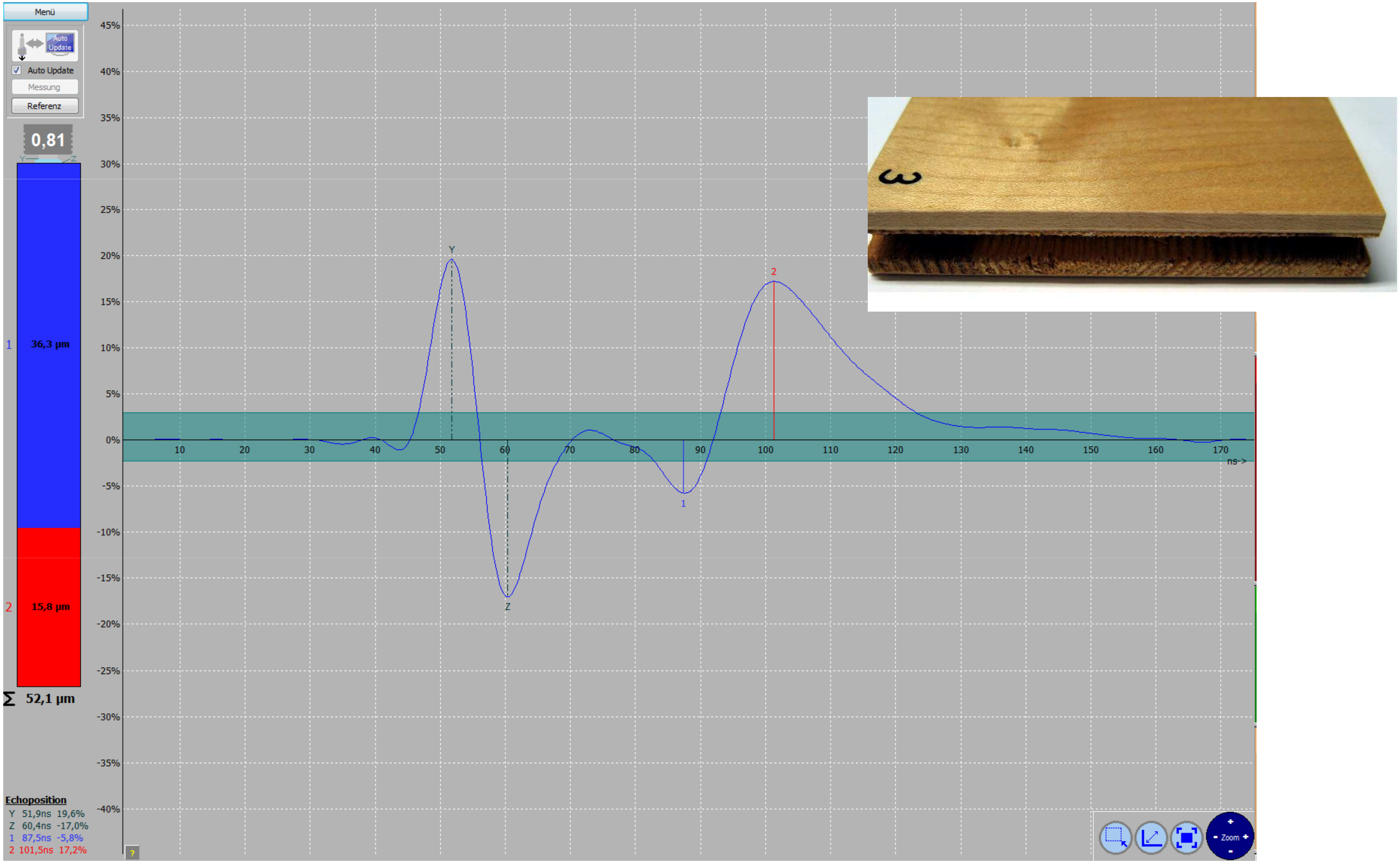
•Using the preset value for industrial coatings
The sound velocities of most industrial coatings range around 2375 m/s ± 15%.

•Using a defined coating thickness
as determined by a calibration standard measured by means of a cross section or a Mikrotom

Coatings on Furniture

- Coating systems in industrial furniture production are subject to extremely high and manifold requirements: high-quality and durable surfaces, special design as well as the latest colour and decor trends.

Measurement of a 2-layer UV-Coating applied on parquet floor



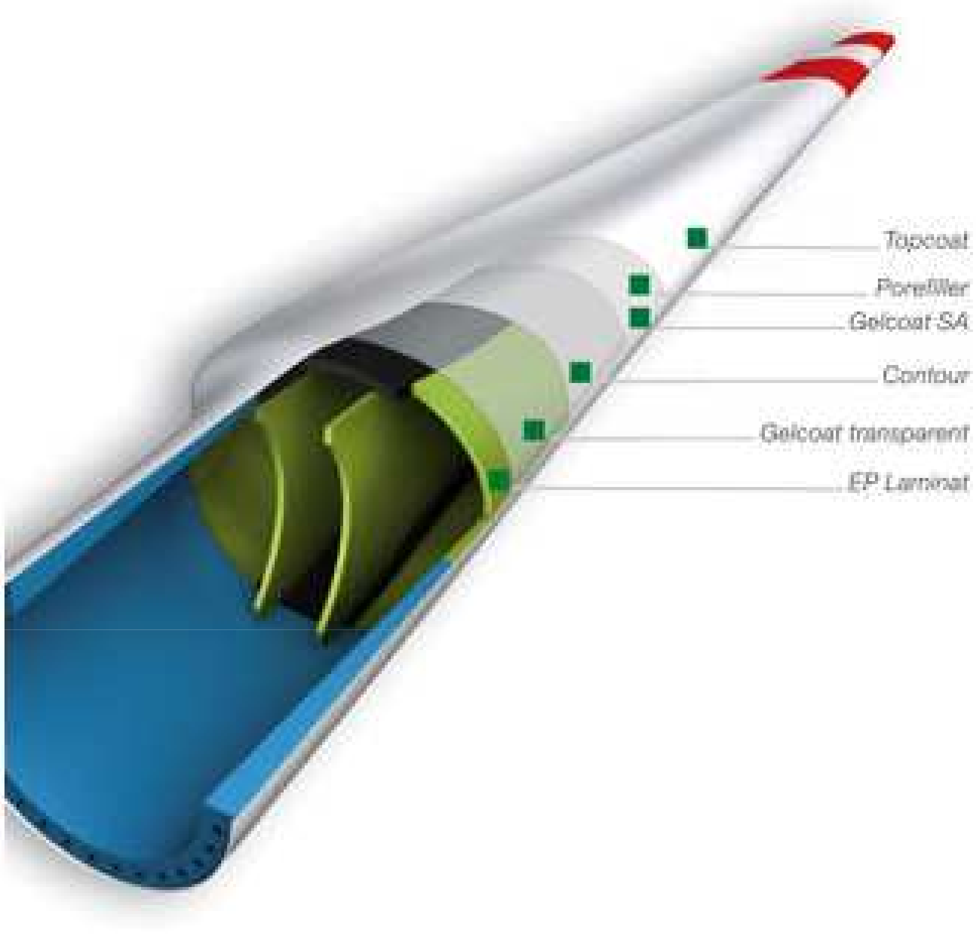
Wind Turbines

- At peak wind speeds of up to 300 km/h the rotor blades have to cope with enormous forces.
- They may bent by more than one meter.
- Adverse weather conditions such as snow, rain, hail, sand heat or UV-radiations put stress on the rotor blades.

Wind Turbines

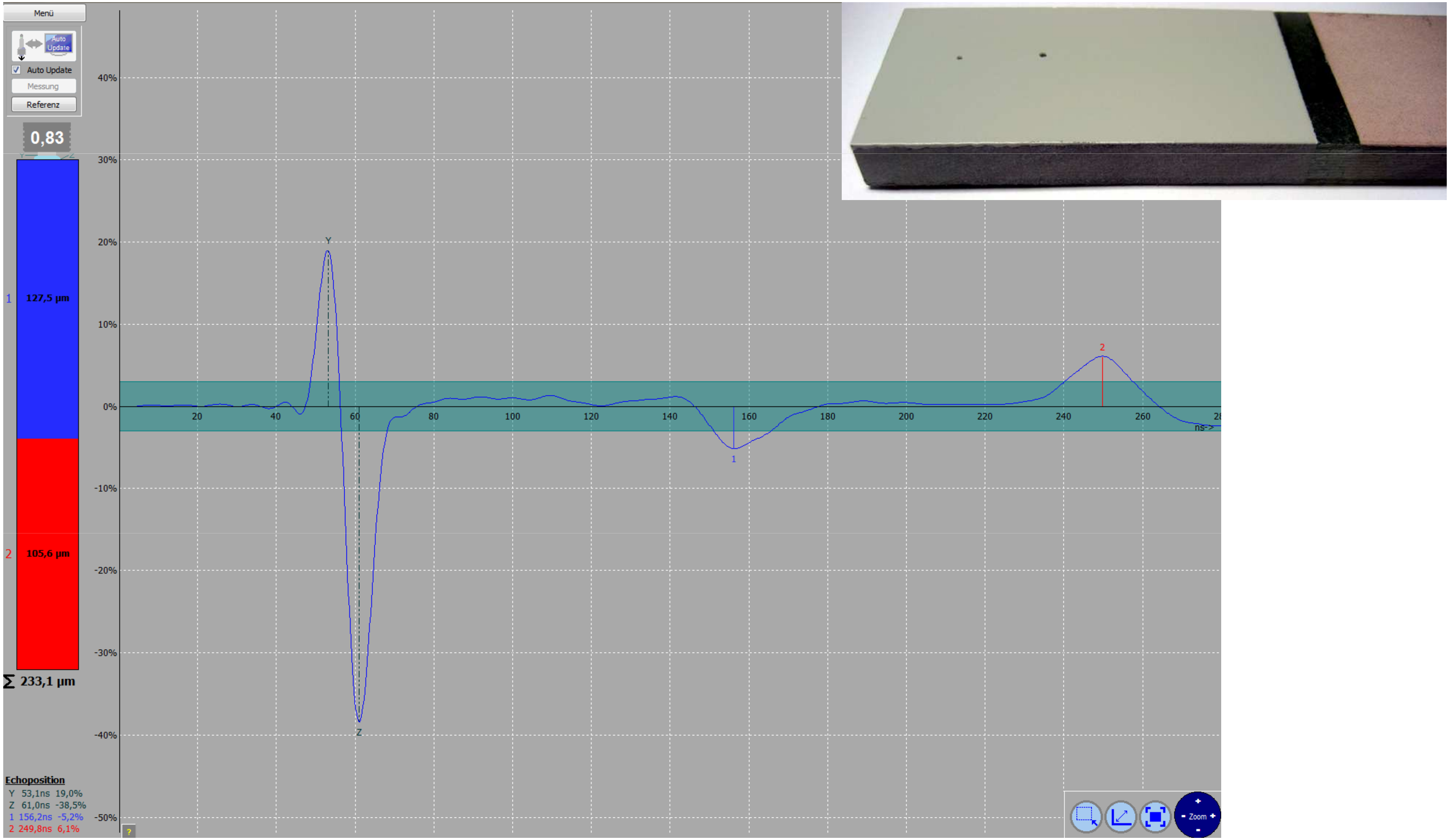
- The quality of coating has to meet high requirements.
- Special coatings must be flexible in order to prevent tension cracks. They must resist to extreme bending of the rotor blades.
- A multi-layer coating made of a two-component polyurethane layer will provide protection for a period of up to 20 years.

Wind Turbines: Coating systems of Rotor Blades



- gelcoat
- filler
- edge protection
- topcoat

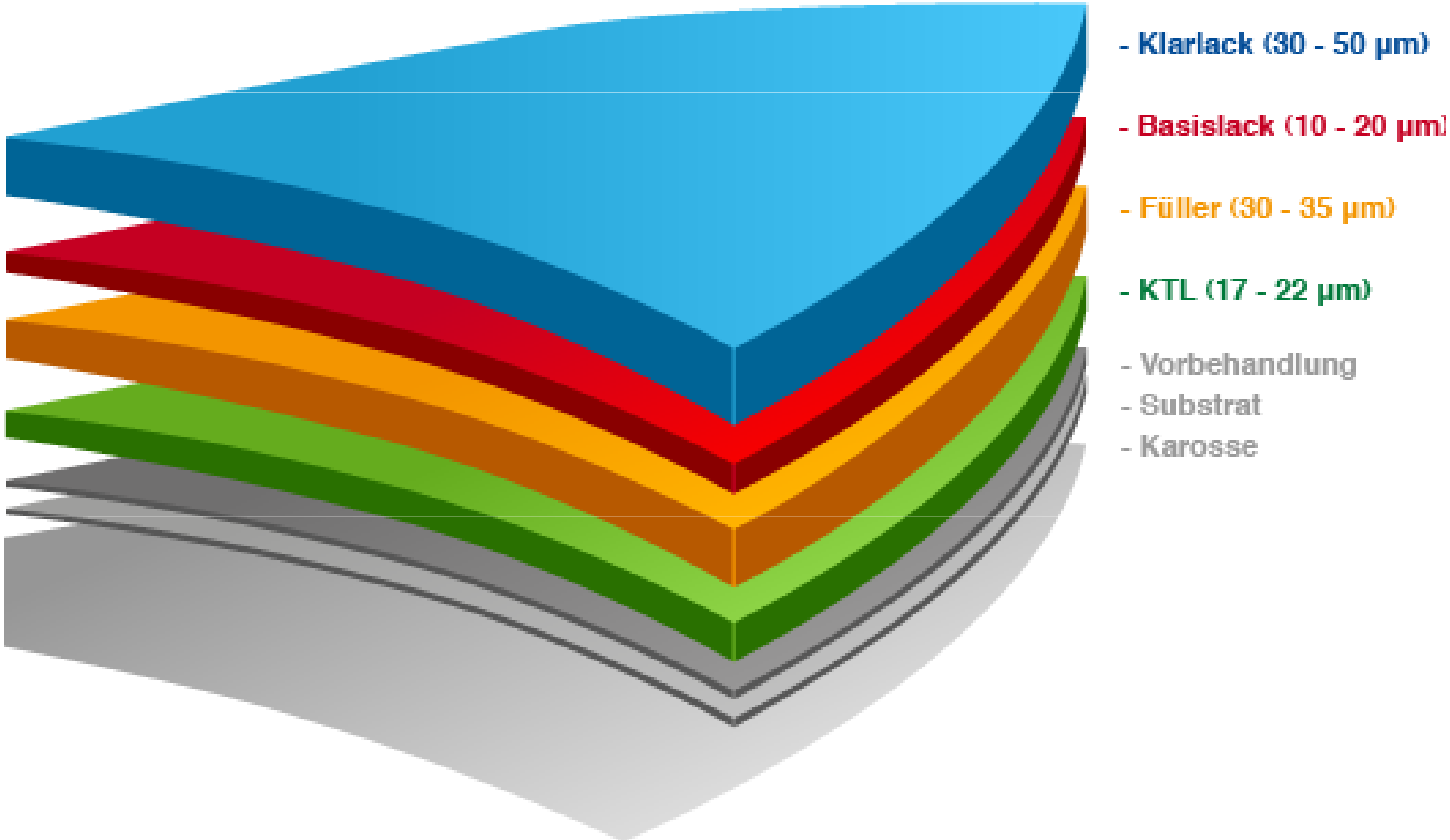
Measurement of a 2-layer PU coating applied on glass reinforced plastic (GRP) – typical rotor blade coating system



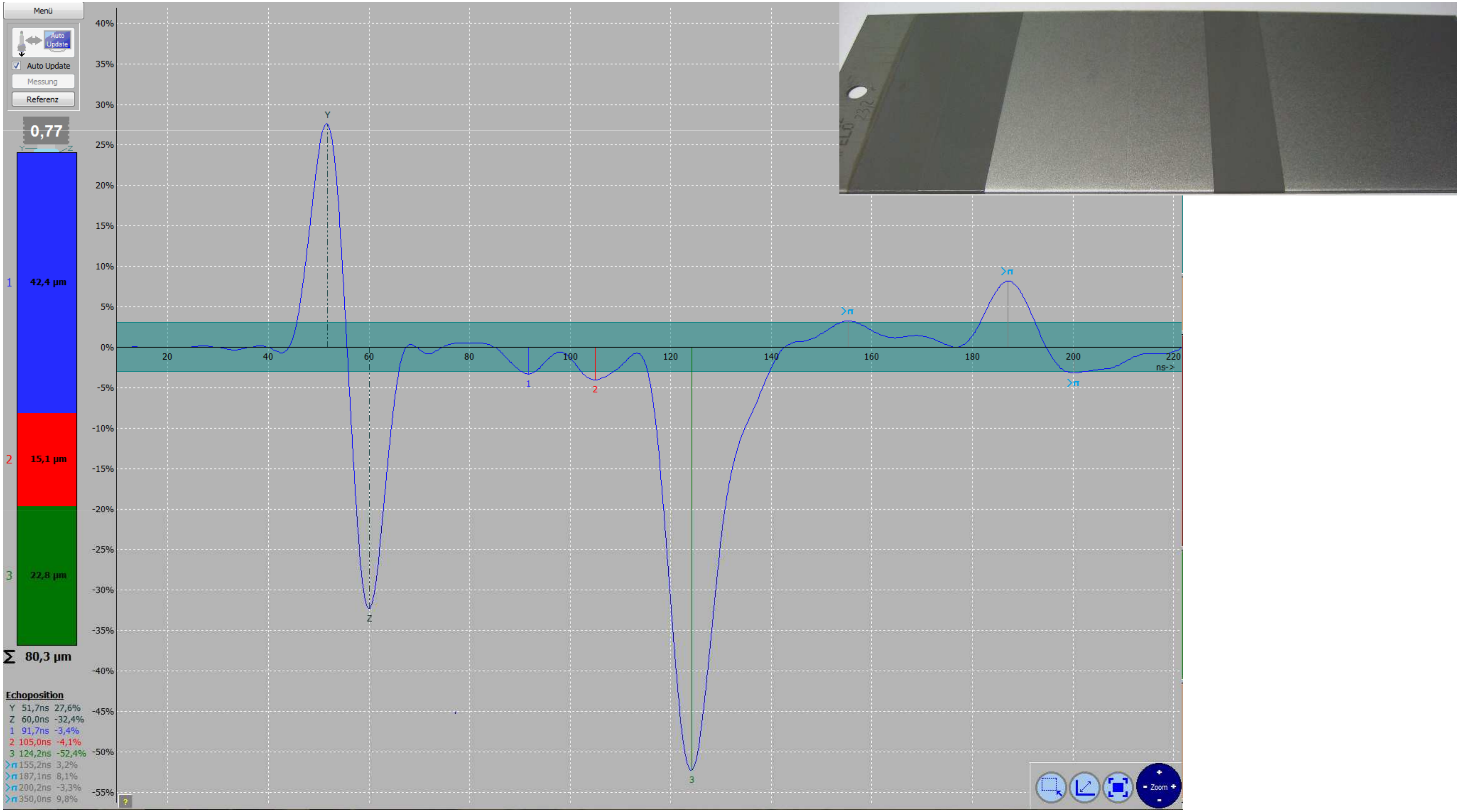
Automotive Finishes

- An immaculate appearance is a decisive factor for a customer to opt for a product.
- The finishing should be glossy and bright and comply with the customers wishes regarding colour.
- Apart from a perfect optical impression, an automotive finishing must fulfil a number of other requirements such as providing corrosion protection to the car body up to the capability to withstand mechanical impacts or adverse weather conditions.

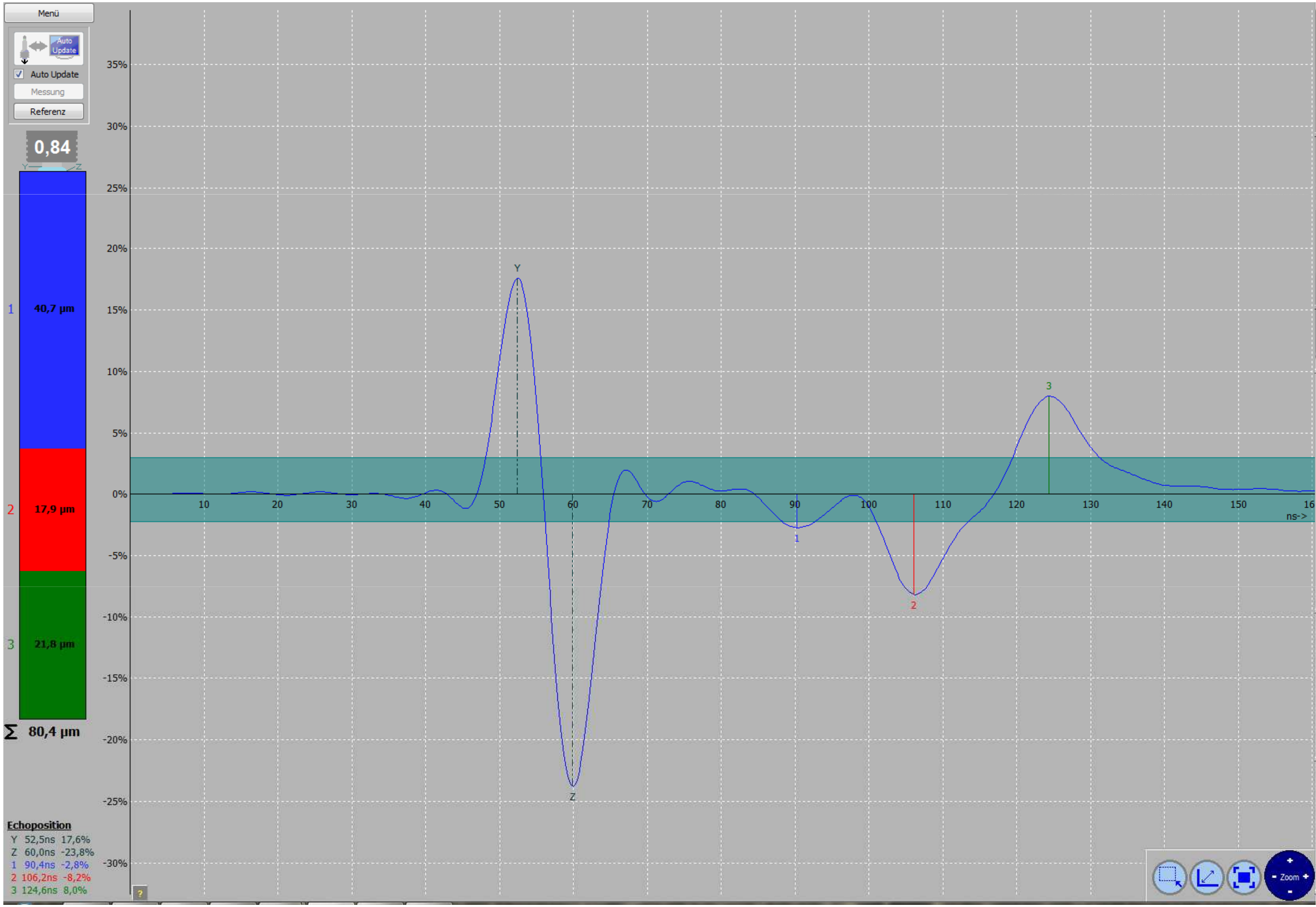
Sequence of Multi-Coat automotive Finishings

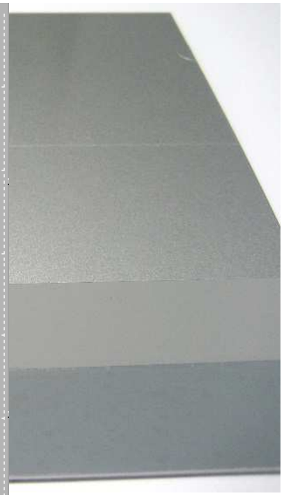


Measuring a 3-coat paint system on metal - KTL (cataforetic dip painting) + Basecoat + Clearcoat

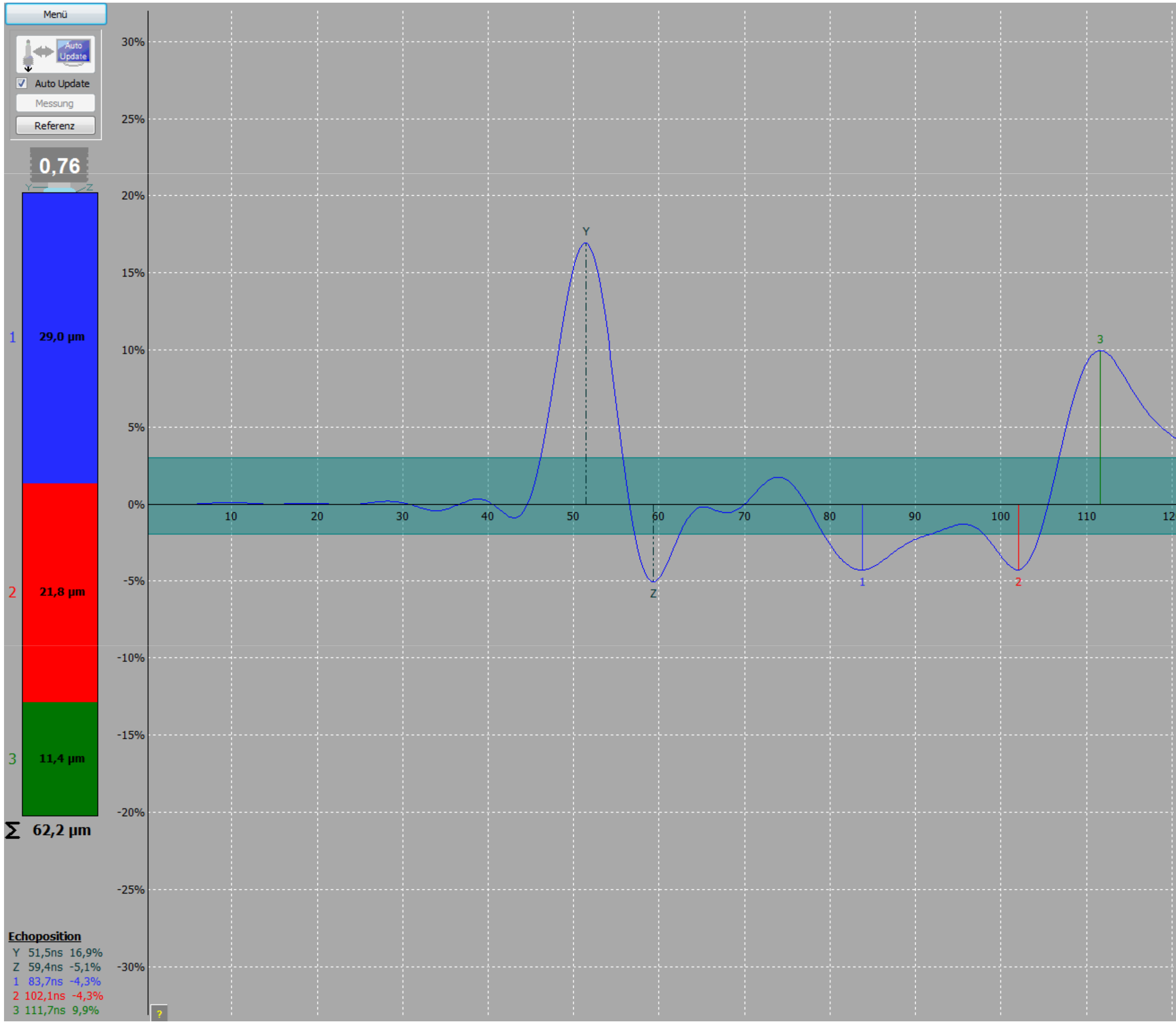


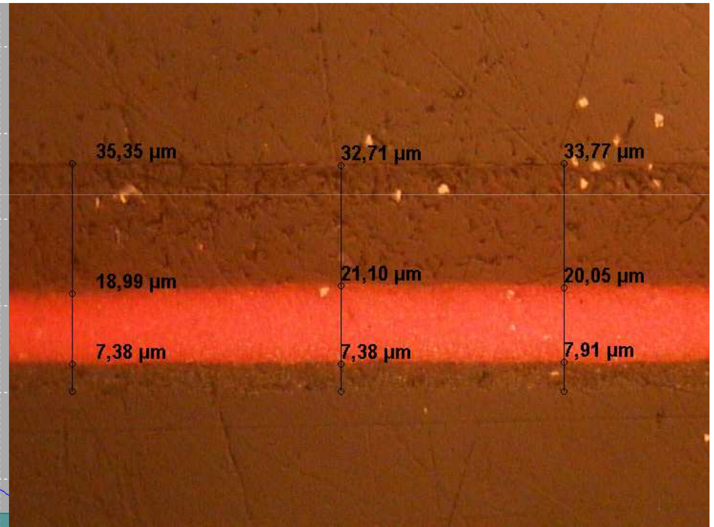
Measurement of a 3-layer paint coating applied on plastic





Measurement of a 3-layer paint coating on an exterior mirror cover





Wide range of applications – some examples

Automotive industry	-	car bodies, single and multi-layer paint coatings on plastics/steel
Automotive suppliers	-	paint on bumpers, hub caps, fittings, automotive components
Paint industry	-	How does paint thickness influence colouring?
Forest industry	-	Furniture lacquer finish, window frames, parquet floors, musical instruments
Ship building / yards	-	Wall, paint or coating thickness of hulls and interior panelling
Aerospace/mainten.	-	paint thickness on aircraft fuselage, wall thickness of thin plastic or metal sheets of aircraft interior panelling
Electrical industry:	-	circuit board coatings, plastics housings of the entrainment industry
Glass processing	-	stove enamels on glass, laminated glass (windscreens)
Plastics processing industry	-	Thickness and wall thickness measurement of painted parts
Miscellaneous	-	Multi-layer thickness measurement of composites for food packaging, thickness measurement of plastic and metal sheets

QuintSonic 7 is suitable for:

- paint on plastic, GRP (glass fibre reinforced plastic) and CRP (carbon fibre reinforced plastic)
- paint or lacquer on wood
- paint on metal and glass
- determination of the individual layers in multi-layer systems
- individual layers of co-extruded plastic foils