Millimeter waves solve a problem of ultrasound-based wall thickness measurements of FRP-components

Millimeter wave testing

How can the quality and wall thickness of FRP-components in chemical plants and power stations (e. g. pipes with and without inliner) be inspected if established test methods like ultrasound fail or show insufficient results? In this case non-contact millimeter wave inspection is a very good alternative.

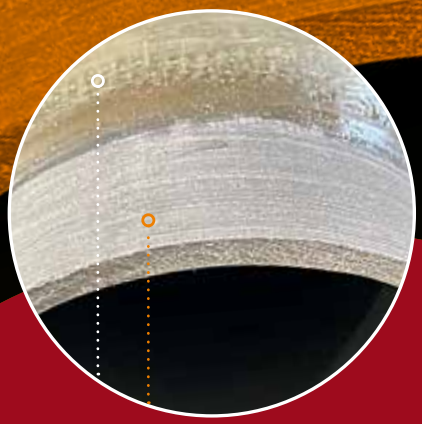
Since the sound impedance of FRP-laminate is much bigger compared to air (appr. 4 orders of magnitude) a delamination internally causes a nearly 100% reflection of ultrasonic waves. Therefore, such a delamination can't be distinguished from wall thickness degradation caused by corrosion or erosion.

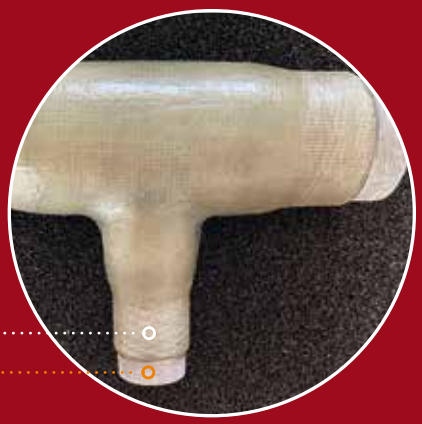
The situation is completely different if you use a millimeter wave based FMCW-radar (frequency modulated continuous wave). This technology works non-contact and does have a major physical advantage for this application.

Since the refractive index in the millimeter range for FRP (appr. 2.0) and air (appr. 1.0) is similar you see a reflectivity of only 30% in case of a delamination. Therefore, millimeter waves propagate beyond such a delamination and a backwall echo can still be detected. This way you can distinguish between a delamination and a wall thickness degradation caused by corrosion or erosion.

This flyer discusses results generated using a FMCW-radar in the range 75 GHz – 110 GHz inspecting different FRP test samples.

Diffusion barrier / PE-inliner in FRP-pipes

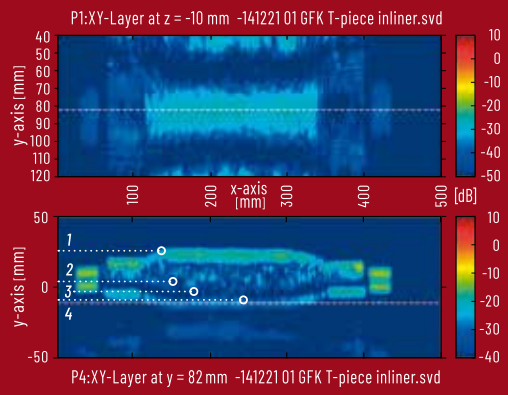




Structure:
- *typically 3-20 mm FRP-laminate*
- *several mm PE-inliner*

Testing:
- *in reflection, from the outer side*
- *during operation!*

Application:
- *chemical industry (aging)*
- *power stations (aging)*
- *machinery and equipment*



C-Scan

showing inside interface between PE-inliner and air (dashed line): surface echo at z = -10 mm

$$d_{PE} = \frac{10\ mm - 1\ mm}{n_{PE}\ (\approx 1.5)} = 6\ mm$$

B-Scan

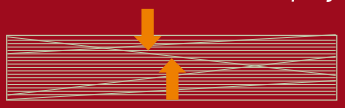
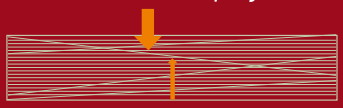
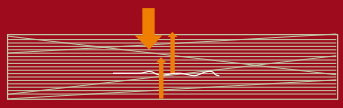
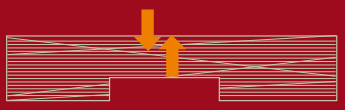
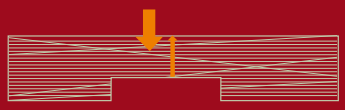
(profile in z-direction) at position see above (dashed line)
1. surface echo (surface FRP-laminate)
2. interface FRP-inliner (PE)
3. PE-volume (fibre free)
4. backwall echo (inside surface PE-inliner)

Physical problem

with US testing: FRP wall thickness measurement, e.g. with 1 MHz

Physical solution

with MW testing: FRP wall thickness measurement, e.g. at 100 GHz

	US-coupling		*MW-coupling (without coupling medium)*
FRP-Wall		*-A- without hidden delamination*	
	100% reflection on the back wall		*30% reflection on the back wall*
FRP-Wall		*-B- with hidden Delamination*	
	100% reflection on the defect Wrong result, there is no back wall echo		*30% reflection on the defect 30% reflection on the back wall Correct result, still there a back wall echo is visible*
FRP-Wall		*-C- with erosion/ corrosion*	
	100% reflection on the eroded/corroded back wall Result in practice indistinguishable from -B-		*30% reflection on the eroded/corroded back wall Result in practice clearly distinguishable from -B-*

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