

Presented at the FIG Congress 2018,
May 6-11, 2018 in Istanbul, Turkey

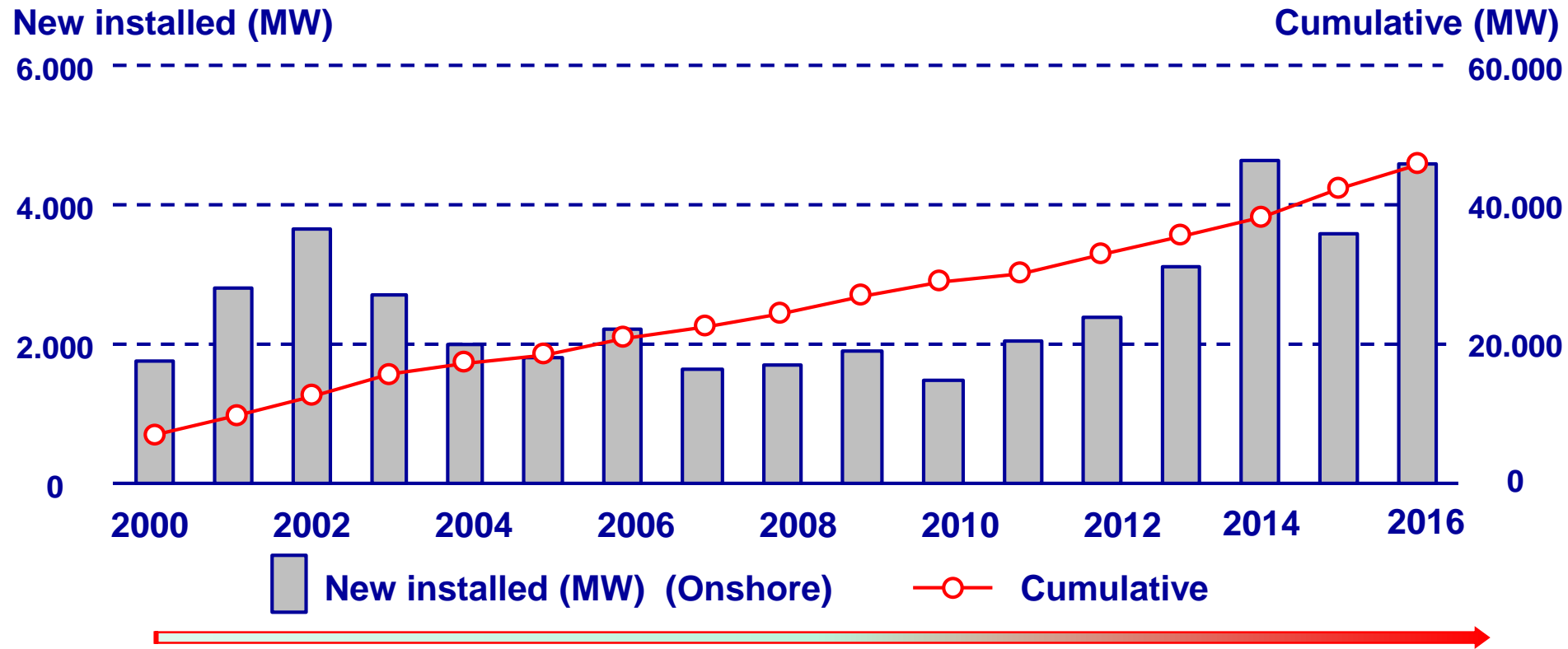
**Prof. Dr. B. Resnik & Daniel Jakubowski
(Bauhaus University of Applied Sciences Berlin,
Germany)**

Application of ultrasonic measurement on concrete foundations of the modern wind energy plants: approaches and experience

- 1. Wind energy - Current development**
- 2. Condition monitoring vs. technical expertise**
- 3. Principle of ultrasound measurements**
- 4. Results of measuring**

Wind energy - Current development

Wind energy is the largest source of electricity production from renewable energy in Germany. Currently there are more than 24 000 wind turbines in use.



Source: www.wind-energie.de

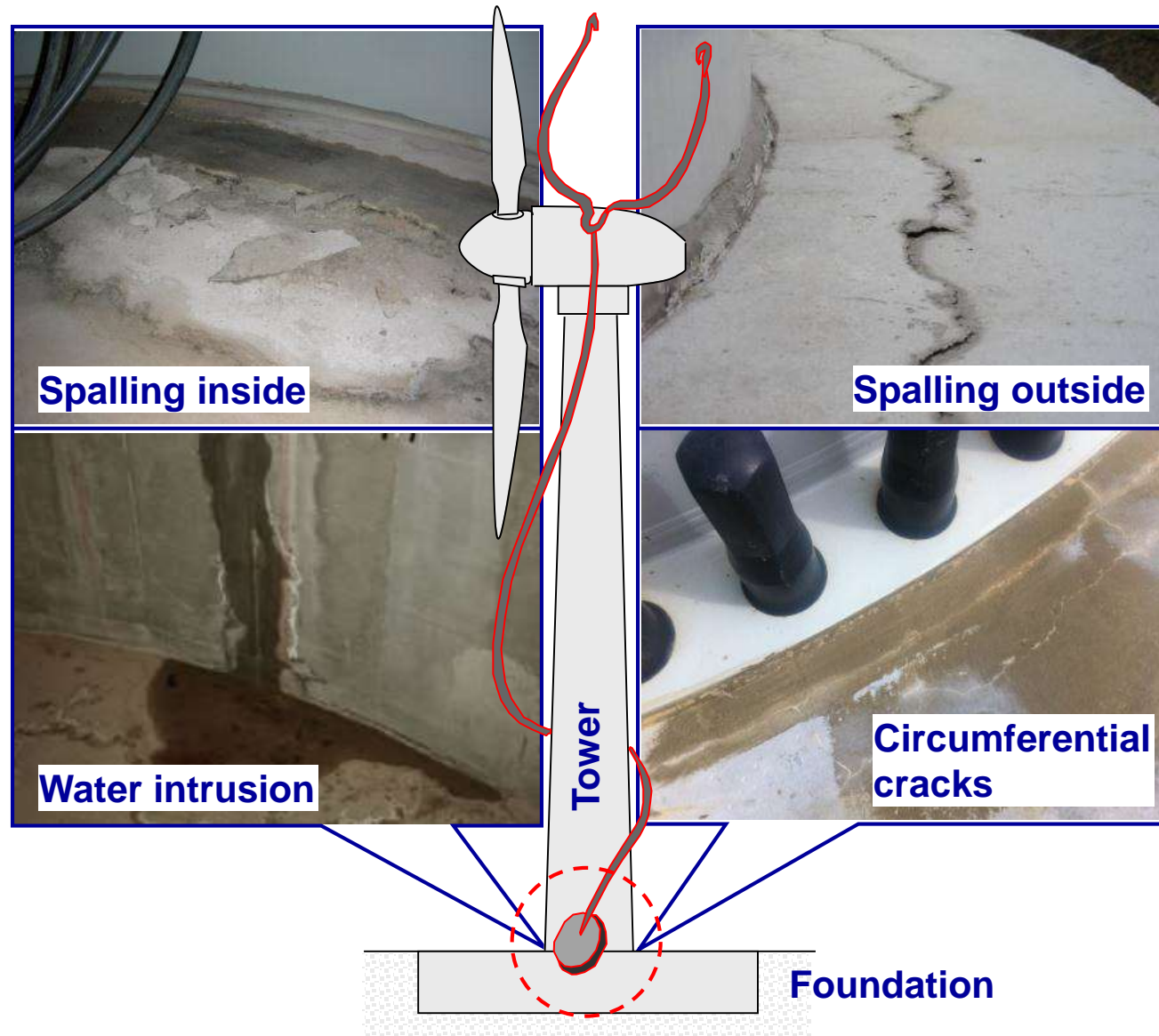
14 – 17 years

More than 10 000 of these wind turbines were built before 2003 and reach the limits of their planned lifespan over the next few years. Therefore, control of their bearing structures plays a particularly important role now.

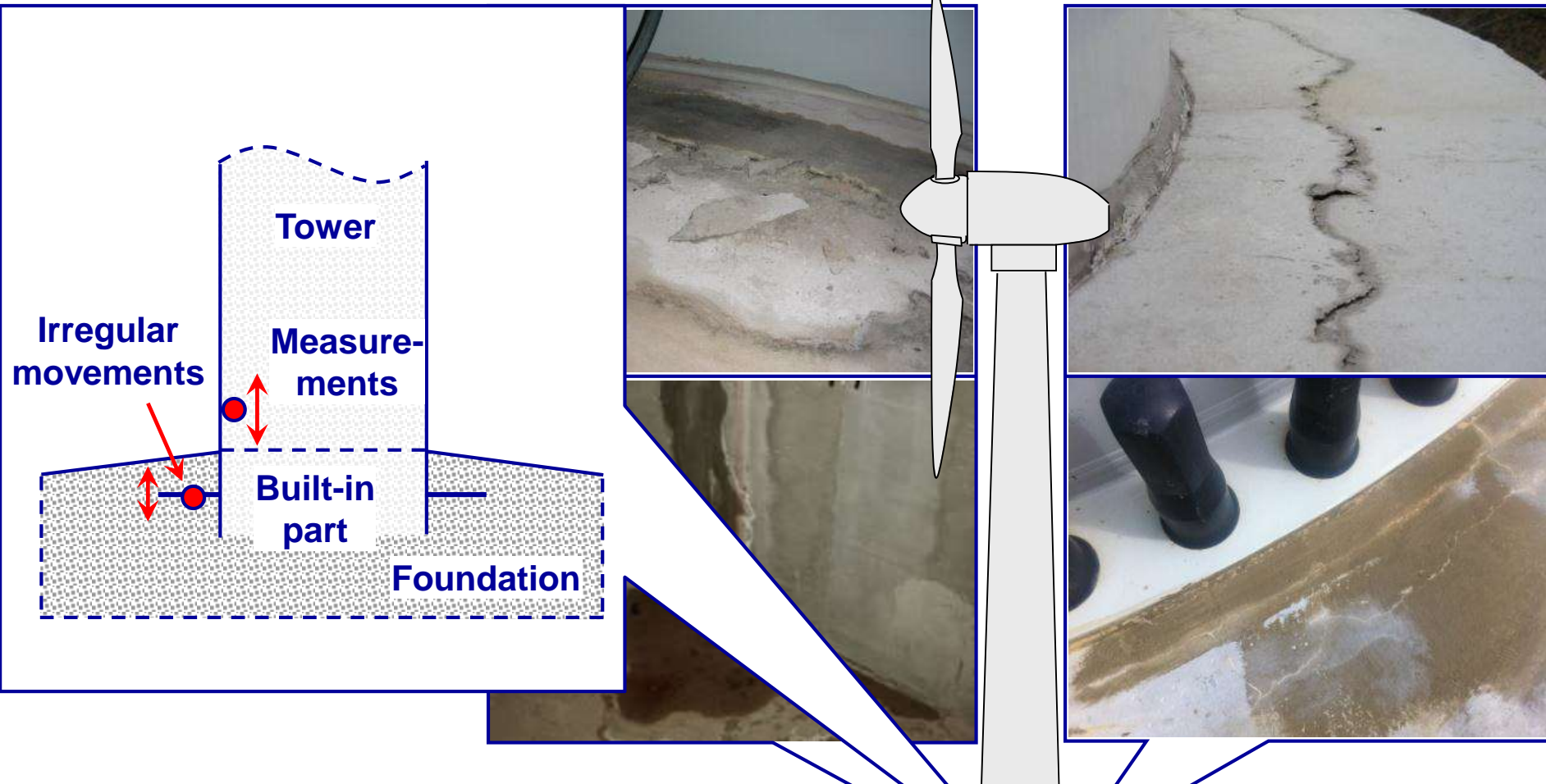


Typical foundation defects in wind turbines

The increasing number of foundation defects in wind turbines shows that one of the main problems is the connection between the tower and the foundation. The damage symptoms are the cracks or spalling in the top of the foundation as well as the water intrusions inside the foundation.



Control of irregular movements of built-in parts



The aim of the measurement is to control the irregular movements of the built-in part of the tower. Unfortunately, it is impossible to measure within the foundation. Measurements on its surface and at the tower provide the important information about the connection between both parts.

Measuring systems for control of irregular movements (FIG Congress 2018, Helsinki, Finland)

Different measurement technologies for control of the connection between tower and foundation have been tested by myself in recent years.



*Distance measurements
with vertical lasers*

A 3D cutaway diagram of a circular foundation. Three vertical laser beams, shown as red dashed lines, originate from sensors on the top edge and point down to small circular markers on the inner surface of the foundation.



*Measurements of
accelerations or
inclinations*

A 3D cutaway diagram of a circular foundation. Several small cube-shaped sensors are distributed across the top and inner surface of the foundation.



Reflectors

A 3D cutaway diagram of a circular foundation. A motorized tachymeter is positioned on the ground inside the foundation. Red dashed lines connect it to three reflectors (circles with a cross) mounted on the inner surface of the foundation.

*Measurements of coordinates
with motorized tachymeter*



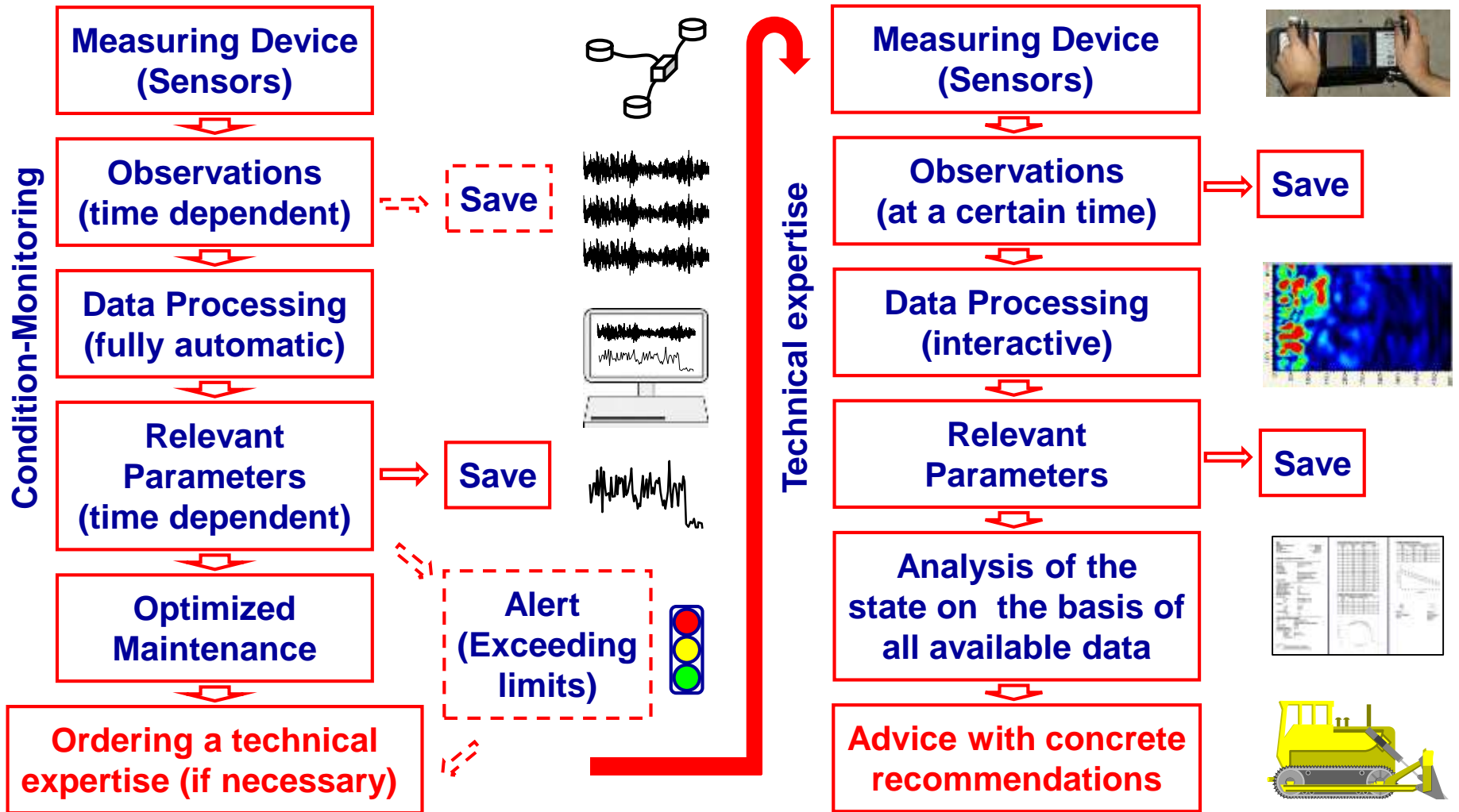
Detectors

A 3D cutaway diagram of a circular foundation. A rotary laser level is positioned on the ground inside the foundation, with a red dashed arrow indicating its rotation. Three vertical detectors, shown as rectangles with double-headed arrows, are mounted on the inner surface of the foundation.

*Measurements of heights
with rotary laser*

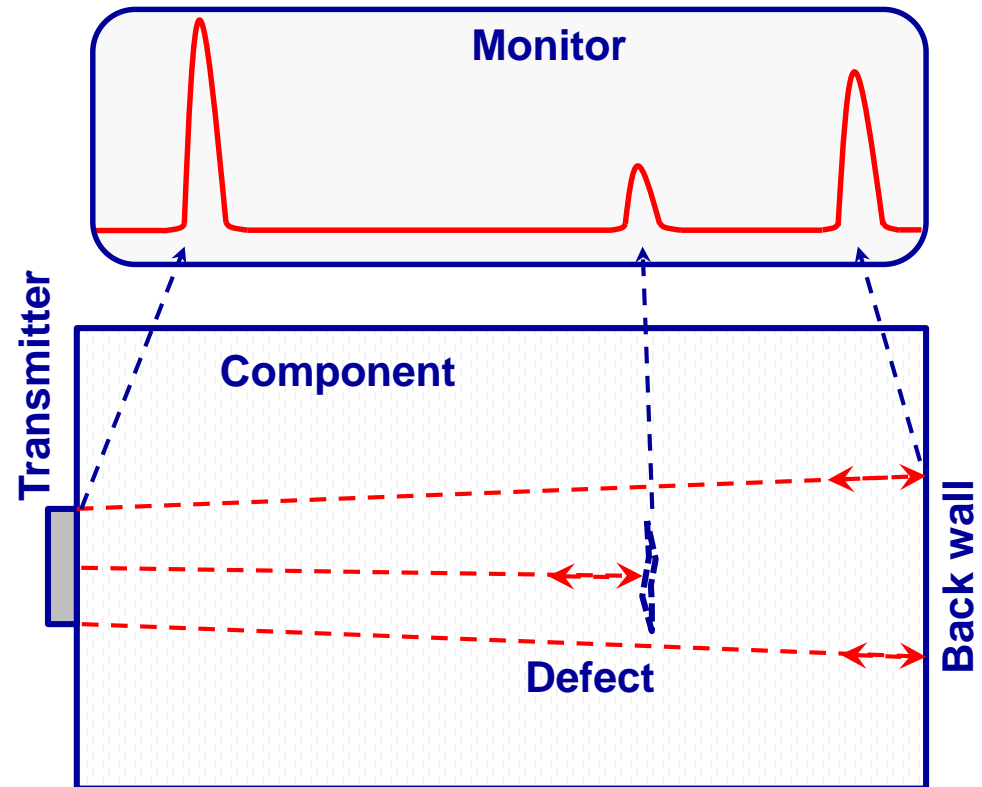
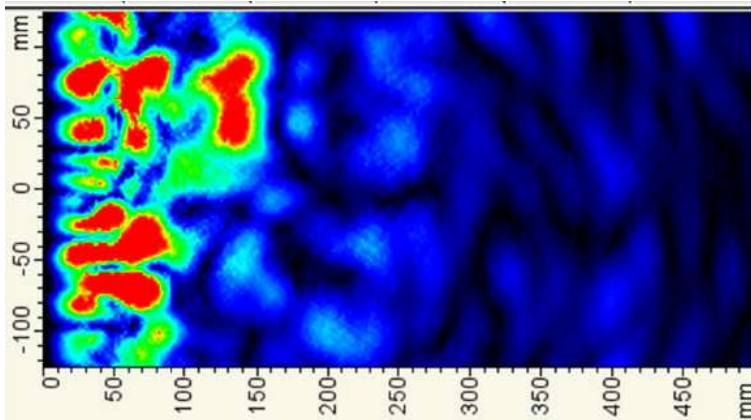
Condition-Monitoring and technical expertise

The main purpose of CM is a prevention of dangerous events and an optimization of maintenance for all systems. The technical expertise is required only for the selected objects and used to define an exact statement about the damage and possible solutions for necessary repairs.



Principle of ultrasound measurements

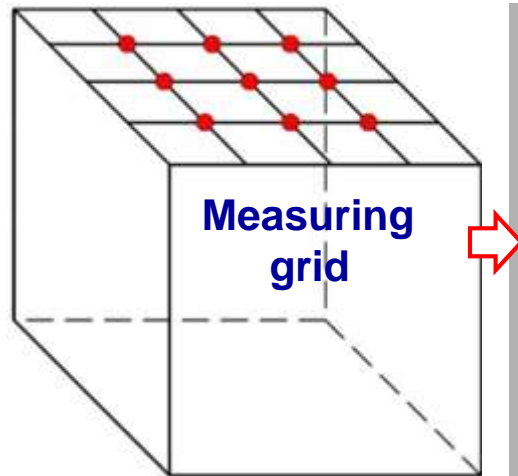
The ultrasonic measurements are suitable for technical expertise. They are based on the principle of the propagation of sound waves within the material. The transmitter sends an impulse into the component. If the impulse hits some defects in material, reflections are generated and are visible on the screen.



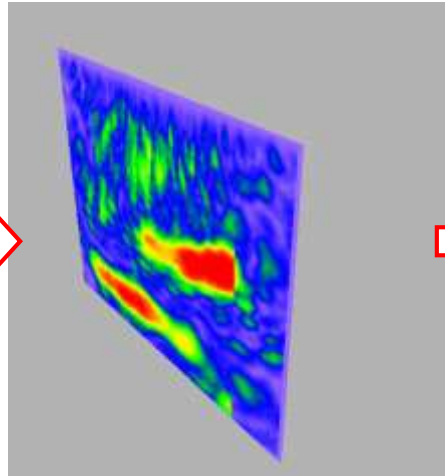
Principle of data evaluation

The original result of an ultrasonic measurements is a two-dimensional image. The third dimension can be created by linear interpolation between ultrasonic images. The distance between each image are the same distance between the marked measuring grids. For getting a spatial impression of the data, the authors developed an evaluating workflow for generating a three-dimensional point cloud.

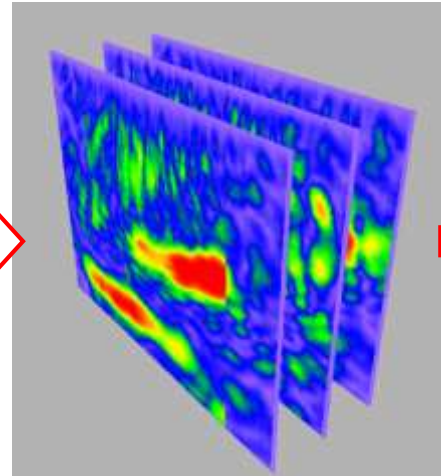
Data recording



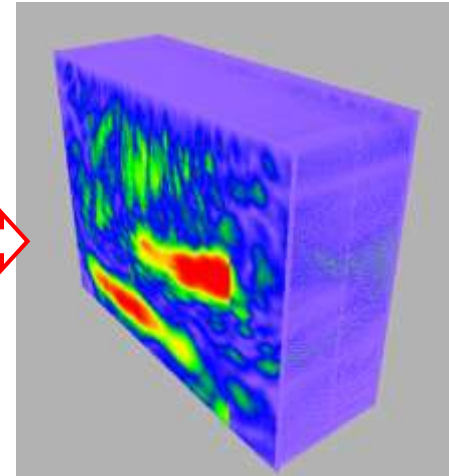
2D-image



Interpolation



3D-Point-Cloud



Results and evaluation of measuring on test pieces

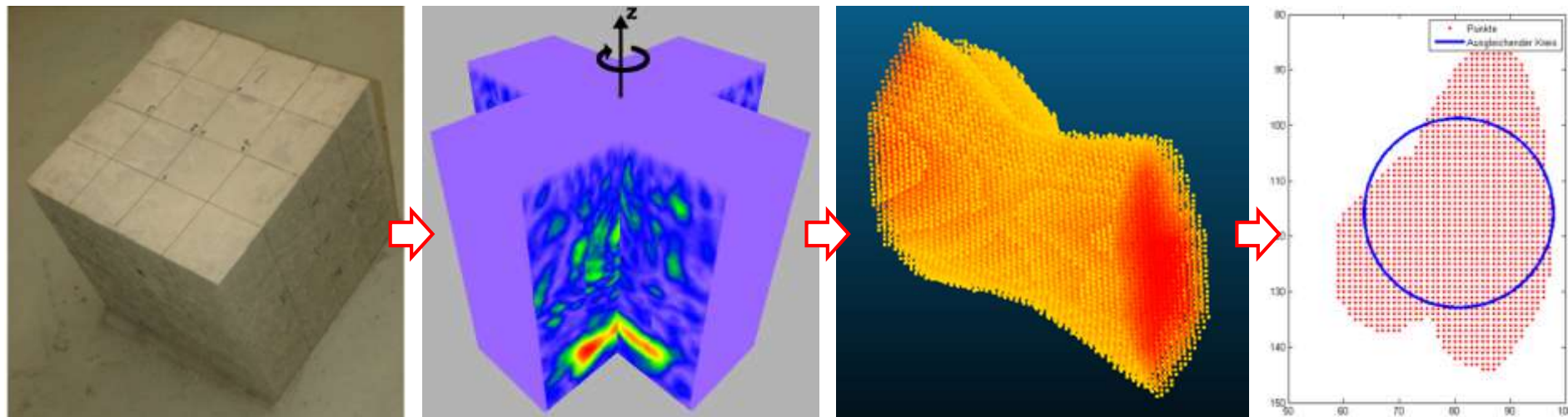
For the first measurements under laboratory conditions 5 concrete cubic test pieces (40 by 40 by 40 cm) were manufactured. They have different defects inside, which should simulate the defects inside the wind turbine foundations. In addition all test pieces had a formwork anchors inside in the form of a tube, which has a radius of 11 mm.

Test piece

Overlapping of measurements

Extracting

Model



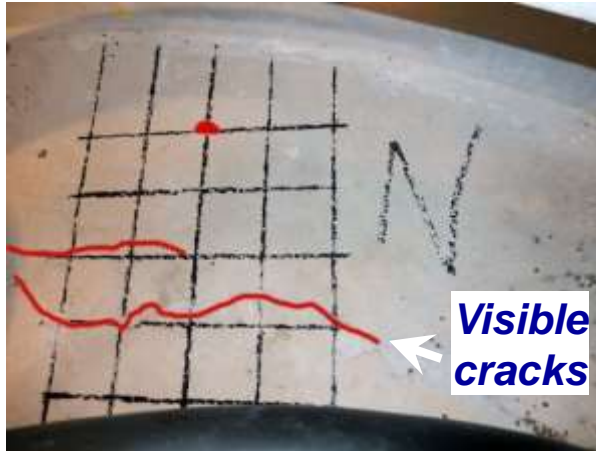
Results of the evaluation (examples):

Test piece	Without overlapping		With overlapping	
	R_M (mm)	s_R (mm)	R_M (mm)	s_R (mm)
1	11,4	1,5	11,5	1,6
2	10,9	3,7	10,8	3,6
3	12,6	3,7	12,1	3,2
4	20,0	10,4	20,0	10,4
5	13,1	3,0	12,4	1,6

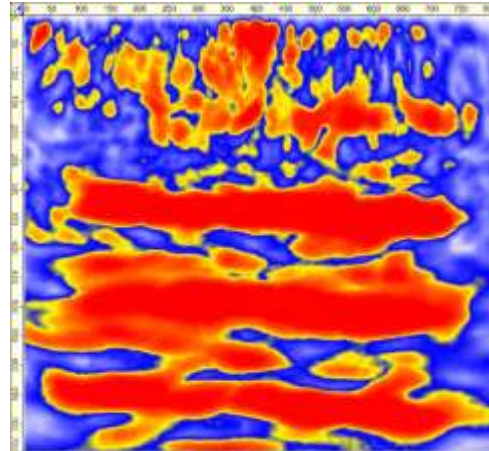
Results of measuring on real wind turbines foundations

The main task of the first measuring experiments on real turbines foundations was a development of a measurement methodology. These experiments will continue in the coming years.

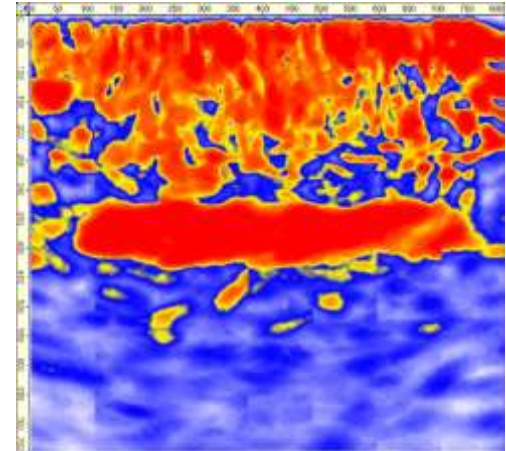
Test-area „North“



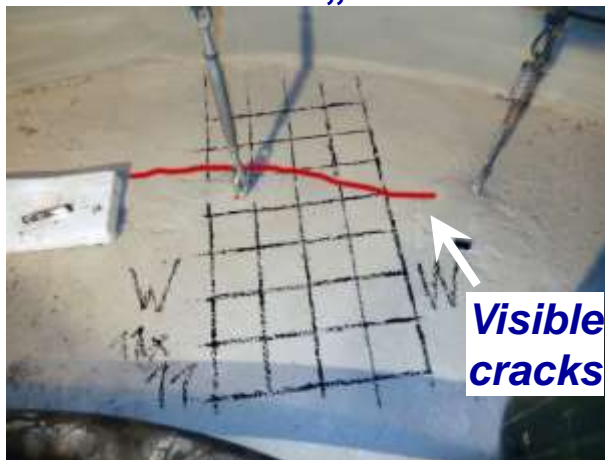
Level „0“



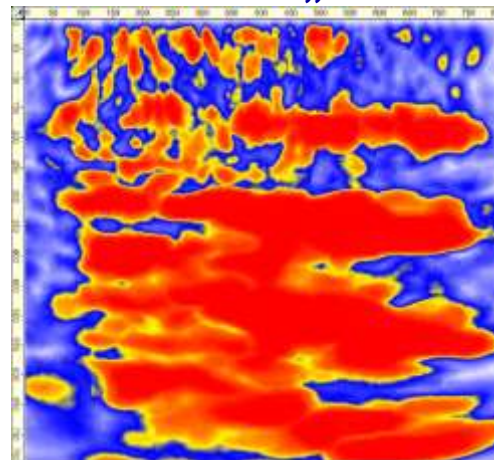
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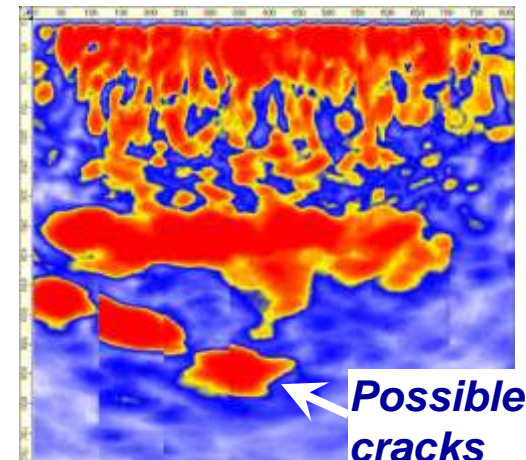
Test-Area „West“



Level „0“



Level „,440“



Conclusion and Outlook

Many wind turbines will be reaching the limits of their planned lifespan in the next couple of years, which makes verification of foundation stability more important. The evaluation based on the presented workflow partially provide very good results. In this way it could generate a three-dimensional point cloud, which makes it possible to combine several measurements of one marked measuring grid. In principle, the interpretation of the data represents the greatest challenge. Partial forms are not shown in detail so that a high level of experience is required to interpret the data correctly.

Thank you very much for your attention!