mecorad

In-Line Radar Technology in Metal Production

Robust Information in Challenging Environments from Liquid Phase to Finished Product

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

eXIST Existenzgründungen aus der Wissenschaft

Europäische Union

ESF Europäischer Sozialfonds für Deutschland

Zusammen. Zukunft. Gestalten.

eit RawMaterials

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

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Vision & Mission

“Our vision is a smoothly running steel & metals industry to answer the growing needs of increasing urbanization by an efficient use of resources. That is why we are on our way to automate for precise inline interventions.“

- Concept of the idea 2015
- Grant EXIST Forschungstransfer 2016 – 2018
- Founding of mecorad 17.09.2018 in Cologne
- 2019 office in Chemnitz
- 2023 Aperam invests in mecorad

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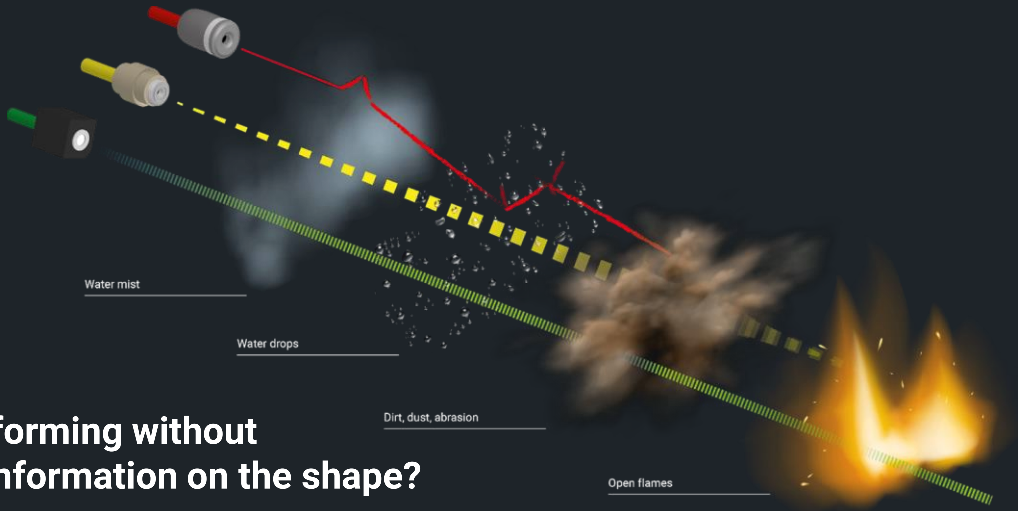
Current issues in hot metals forming

- Harsh conditions & malfunction of sensors
- Production without sufficient information
- Inefficient processes
- Yield losses
- High CO2 emissions on the road to a circular economy

Transparent shapes for Fabrication 2.0



Metals forming without in-line information on the shape?

Common sensor technologies, such as laser or ultrasound, often cannot cope with extreme operating conditions in metallurgy and metals forming. The ambient atmosphere simply blocks their view.
This blind production without data causes inefficiency, product, financial & time loss, and huge amounts of unnecessary CO2.
mecorad's radar technology is unharmed by these conditions and delivers precise & robust information for digital production & AI.

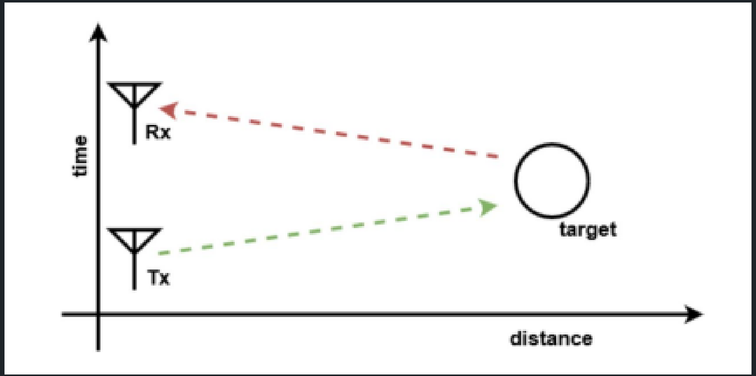
Radar brief overview

RADAR - **ra**dio **d**etection **a**nd **r**anging

technologies to detect and range objects with the help of electromagnetic waves

The measured distance is proportional to the time between sending an electromagnetic pulse and receiving its reflection from the target

A challenge for every radar system is a precise measurement for this time period



FMCW Radar Technology

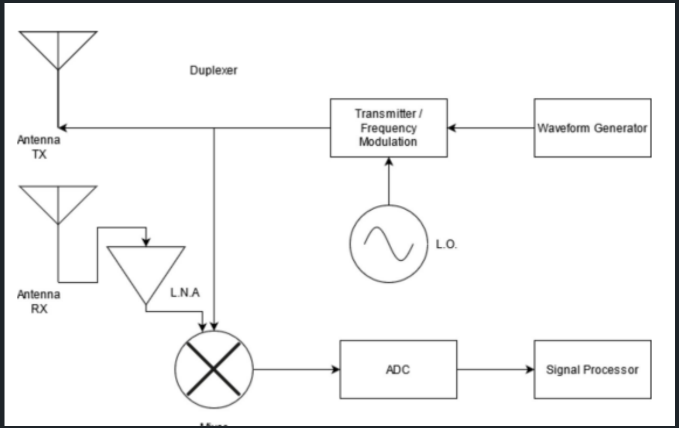
FMCW - frequency modulated continuous wave

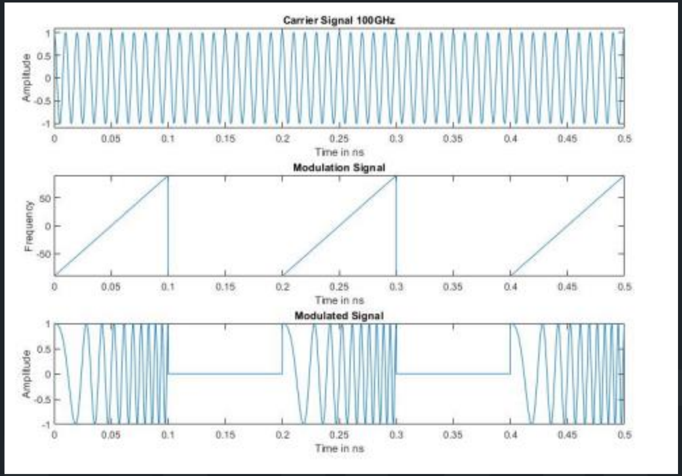
Transmitter and Receiver are active at the same time

Instead of a pulse a frequency modulated *chirp* signal is sent

A *sawtooth* chirp can be defined by:

chirp duration	τ
center frequency	f_c
bandwidth	BW
measurement period	T





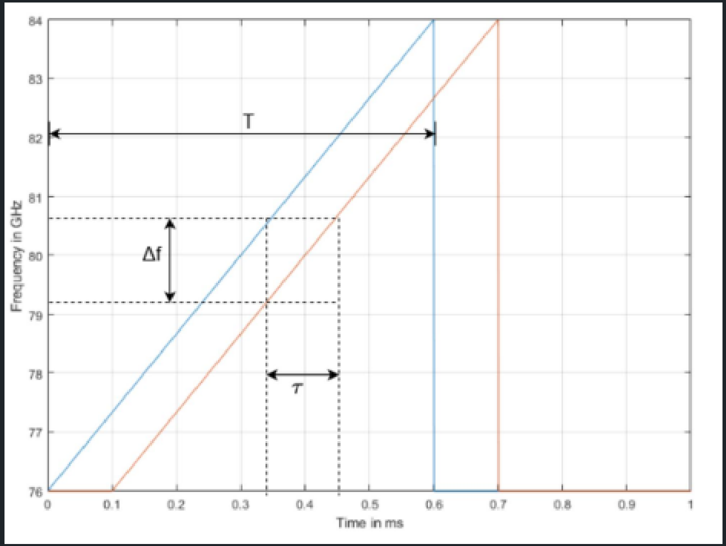
FMCW

In a mixer the currently sent and received signal are *down converted,* which gives an output signal equal to the difference in frequencies of the input signals Δf

The output signal is sampled

Frequency analysis is done after Fourier-transformation

Δf can be detected with a **very high precision** and respectively the time difference or the distance to the object



$$R = \frac{c_0 T}{2BW} \Delta f$$

Sensor platform mecorad M122-4

122 GHz-band with up to 5 GHz bandwidth

High-performance embedded system as calculation unit

Transmitting power: <1,6mW

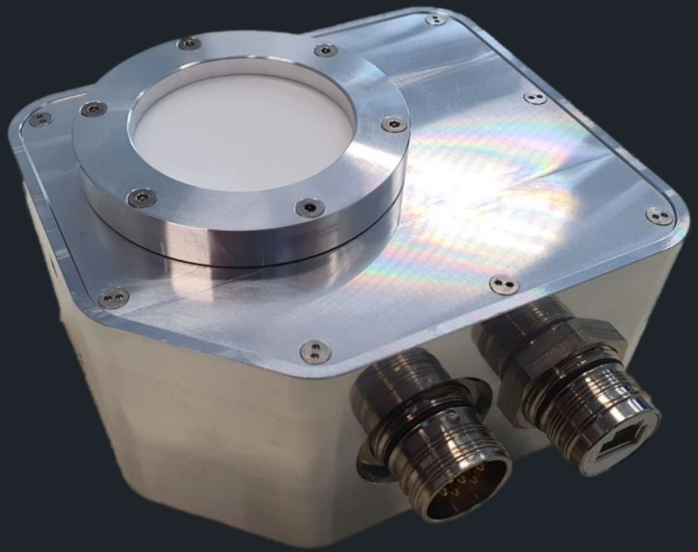
Measurement rate: ~75 Hz

Measurement distance: 25m (5m for high accuracy)

No temperature drift

Measurement through various kinds of refractory material

Sensor protected from dust and water: IP68



Portfolio

Solutions

wtl series

solutions for width, thickness & length

Single sensor products

distance sensor series

available up to micrometer absolute accuracy & precision

level sensor series

level & freeboard of melts & slags

scout sensor series

precise detection of hot & cold material

FMCW Radar Resolution and Distance measurement

Radial resolution is strongly defined by Bandwidth

$$\Delta R = \frac{c_0}{2B}$$

Targets in the same resolution unit with the same reflectiveness can‘t be differentiated

Accuracy for single targets can be much higher

FMCW Radar Resolution and Distance measurement

On a classic (single transceiver) RADAR two or three dimensional detection is achieved by moving (e.g. rotating) the Radar Antenna

The angular resolution is depending on the distance to target, and is measured in degree (azimuth and elevation)

Minimum distance that two equally reflecting objects needs to be apart from each other to be differentiated

The angle is defined by the size of the antenna (aperture) and the used wavelength (big apertures or small wavelength -> small angle -> high resolution)

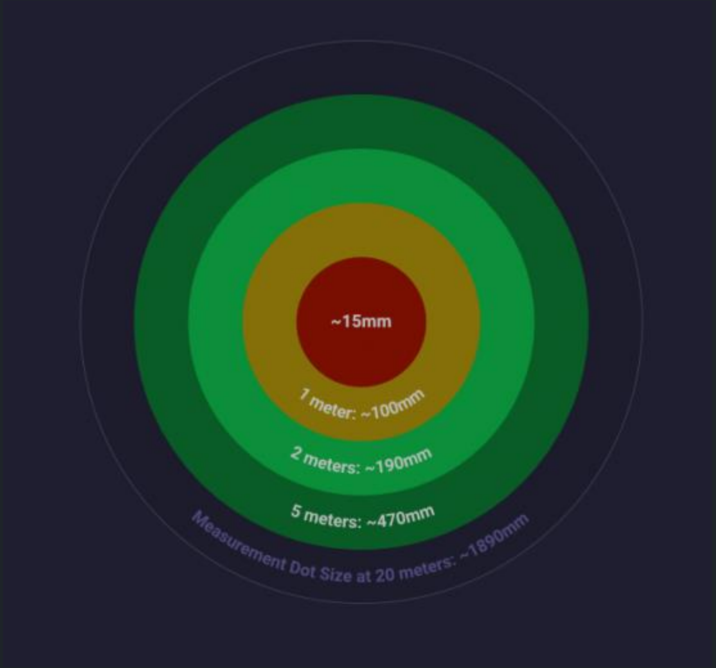
At *Extremely High Frequency (>30GHz)*: Use quasi-optical lenses

The location of a single object can be detected with much higher accuracy !

Measurement Dot

The measurement does not take place on a point but over a surface on the object to be measured.

The surface area is dependent on the Distance to the sensor

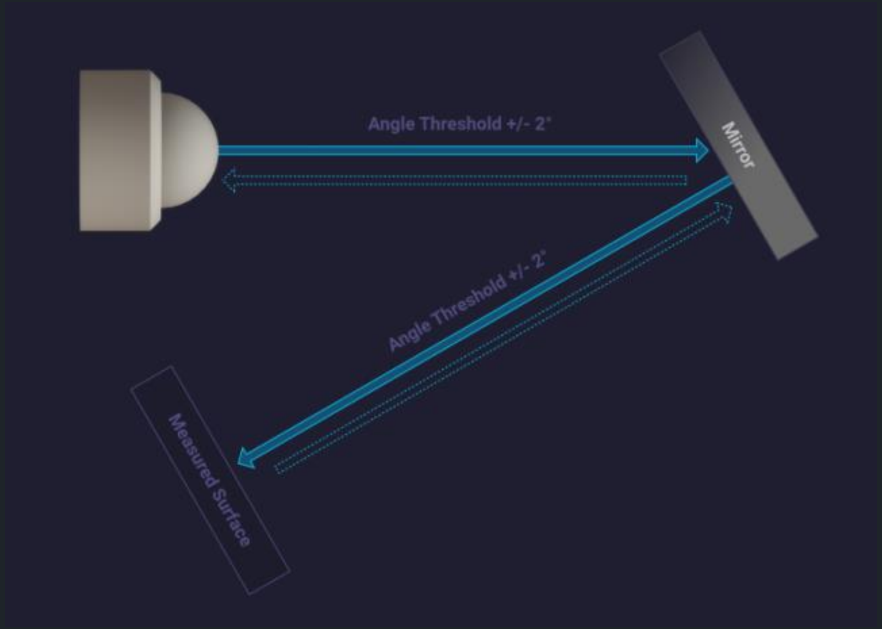


Using Mirrors

Radar signals can be mirrored

Thus, it is possible to reach even hard to reach areas

A plain metal block can be used as a Mirror



Penetrating surfaces

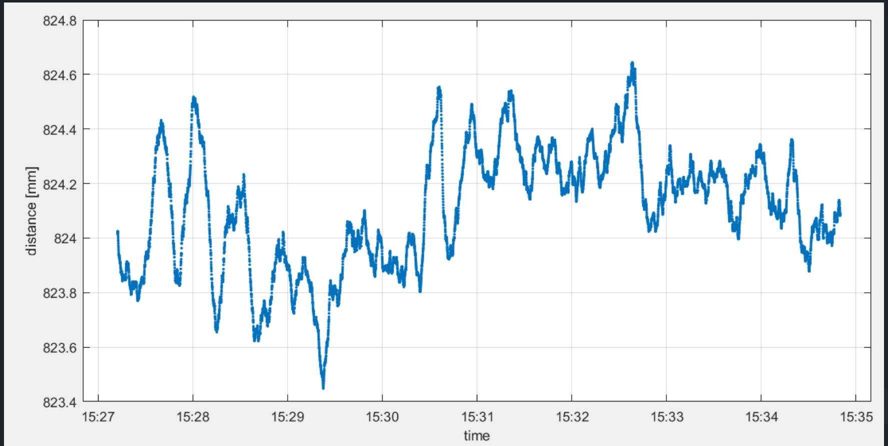
Radar signals can penetrate various materials depending on the frequency and the material properties

The properties can be used to protect the sensor. Many ceramics & refractories are almost transparent

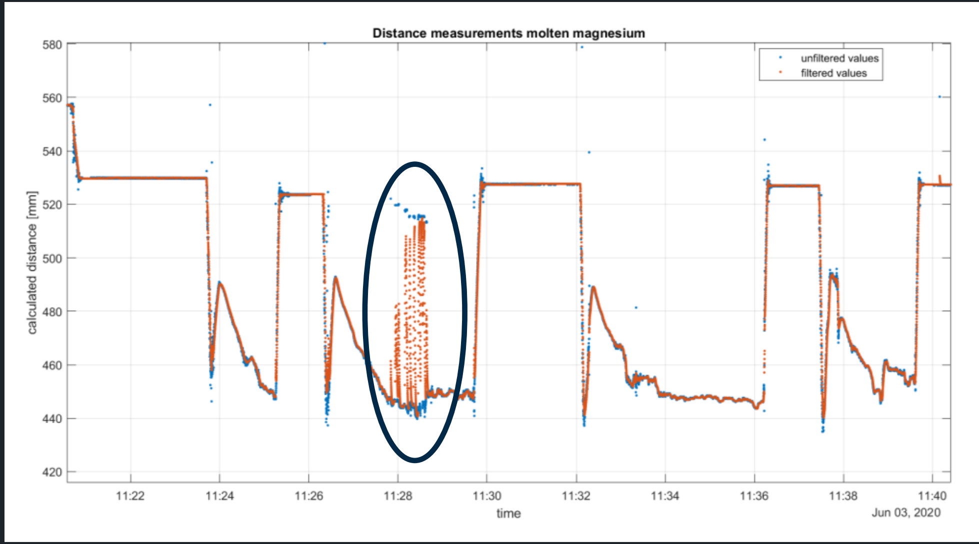
The properties can be used to analyze the material that is penetrated without destruction

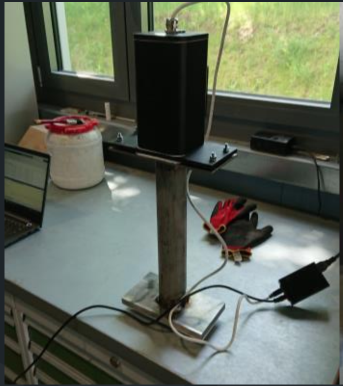
Level in extreme conditions

- Furnace level
- Converter for lance distancing
- Transport ladle
- De-slagging station



Level in extreme conditions

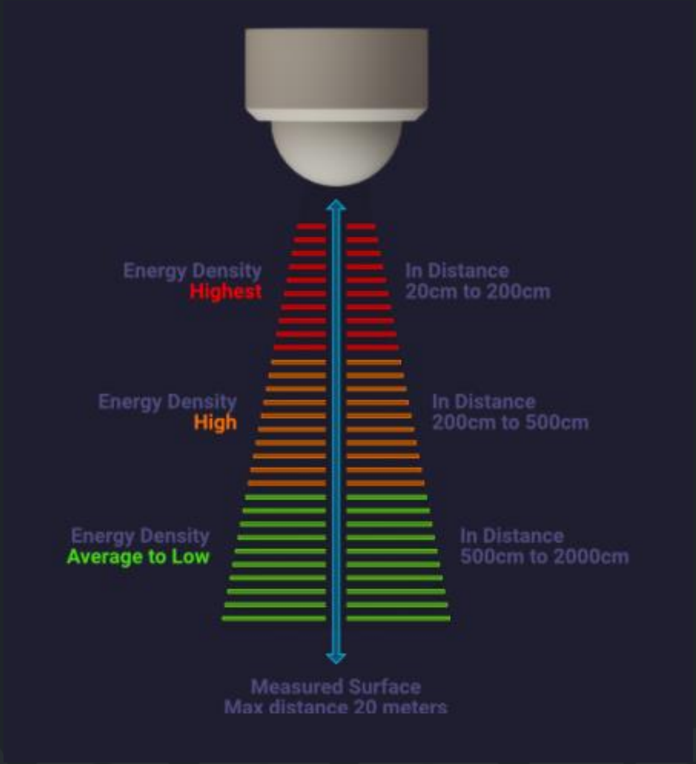




Signal Strength

The Signal Strength decreases with a rate of $1/(2r)^2$, where r is the distance to the object

Higher distances are leading to more noise and may lead to a lower precision



Object Surfaces

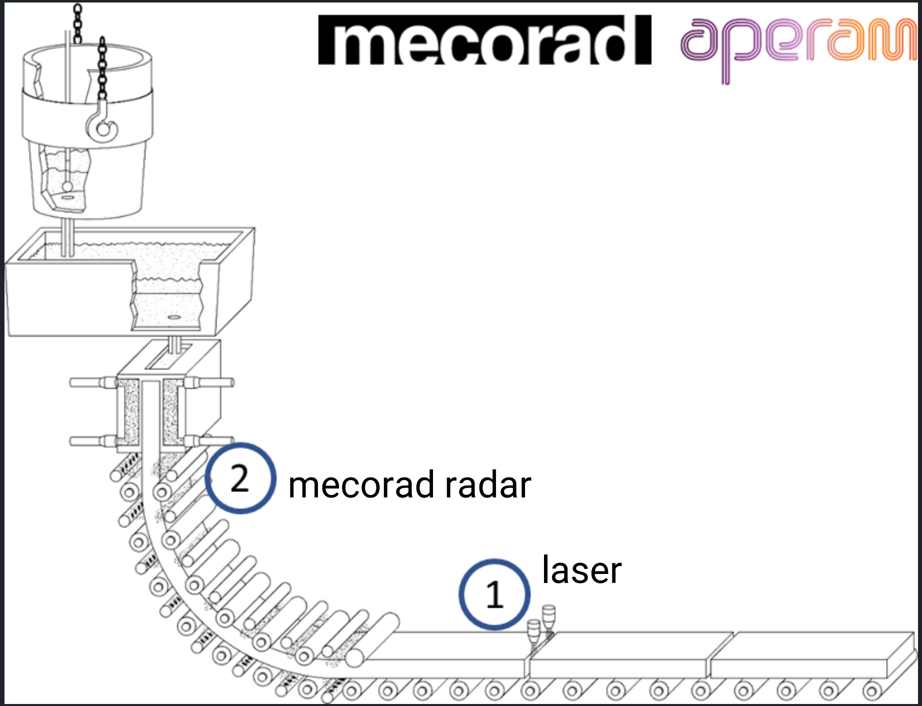
Due to the aforementioned properties, radar works with highly diverse surfaces

The same setup can be used for polished surfaces as well as for very rough or irregular surfaces

This can be an advantage over optical systems, where high reflective surfaces often lead to insufficient results

Aluminum surfaces have excellent properties for a radar measurement

Continuous casting & slabs

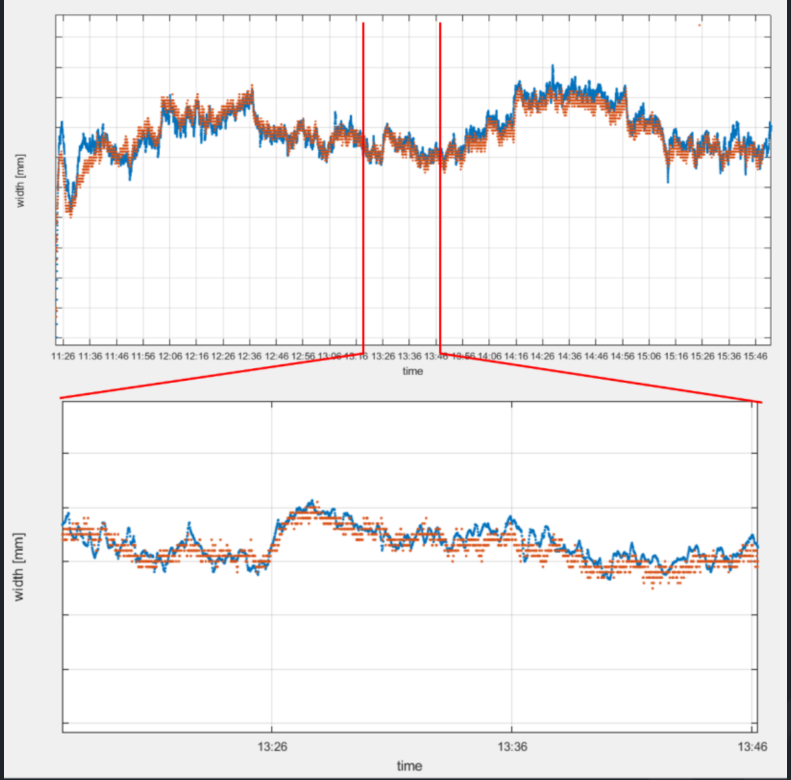


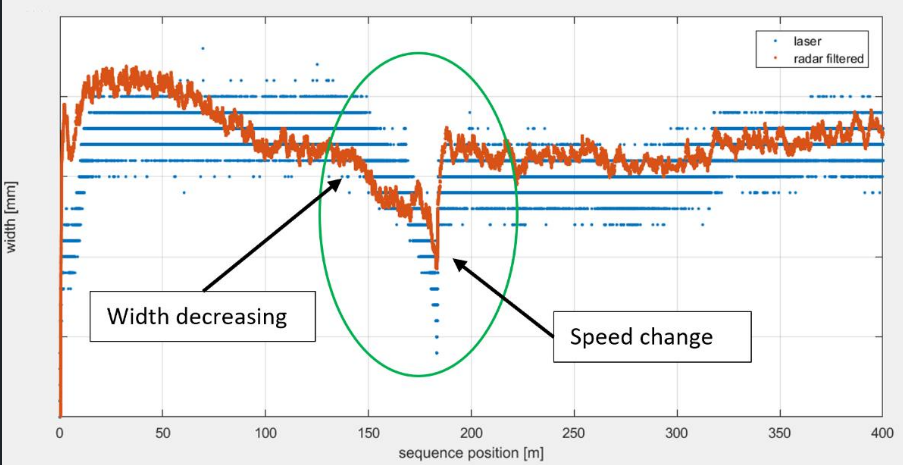
Extremely challenging environments can be handled with high accuracy

Material composition has no influence on measurement

Material thickness has no influence on measurement quality

Continuous casting & slabs





Width measurement of sequence on 20.03.2019, 11:20 - 15:50

Precision and Accuracy

The precision/accuracy is *usually* taken as three times Standard Deviation (3σ) → 99.73%

Precision

repeatability → multiple measurements in a static system

reproducibility → multiple measurements in equivalent static systems

Accuracy

difference between the *mean* of the measurements and the *true value*

Low accuracy due to low precision

Low accuracy even with high precision

Pictures: Public Domain @ Wikimedia Commons

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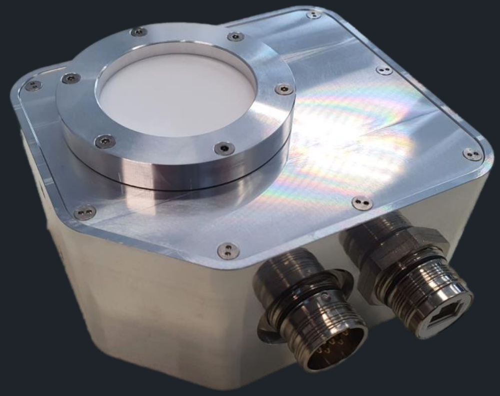
Precision @ 1m distance: < **0.0015mm**

Accuracy @ 1m distance:

Distance	Range	Accuracy
1m	+/- 200mm	< 10µm
Two-sensor-solution (wtl series)	+/- 200mm	~ +/- 20µm
In-line cold material (2 sensors)	+/- 100mm	up to +/- 10µm
In-line hot rolling (2 sensors)	+/- 200mm	up to +/- 50µm



Temperature compensated measurement
Inside temperature from -20°C to 70°C
(Peak) outside temperature 260°C or 1400°C (depending on front plate)

Accuracy over distance – Systematic Errors

A systematic error in accuracy over distance can be handled by calibration and adjustment of the measurement system

Most measurement systems can only be calibrated for a very specific measurement range
- accuracy over distance is usually not constant
- limitations by the used technology

In reality not every measurement system can be described completely
So the actual error in accuracy over distance is always > 0

Systematic errors reducing the accuracy

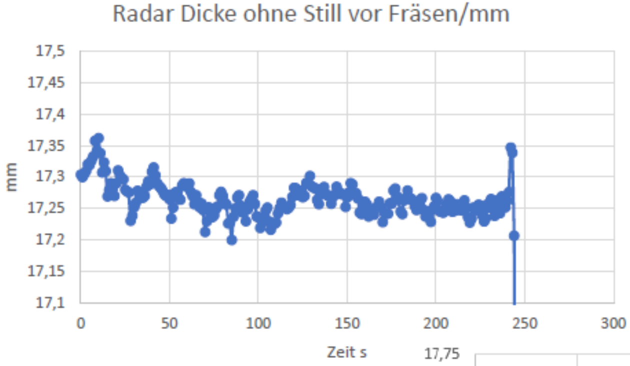
Environment:
- water surfaces
- conductive materials
- highly loaded line of sight
- temperature, especially rapid changes but also changes over time

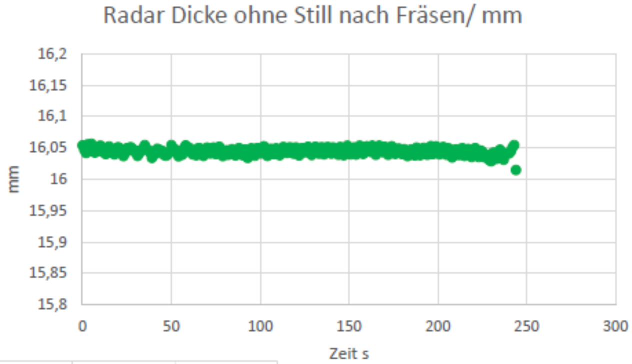
Errors induced by target object:
- very rough surfaces
- curved surfaces / changing angles to sensor
- movement (radial)

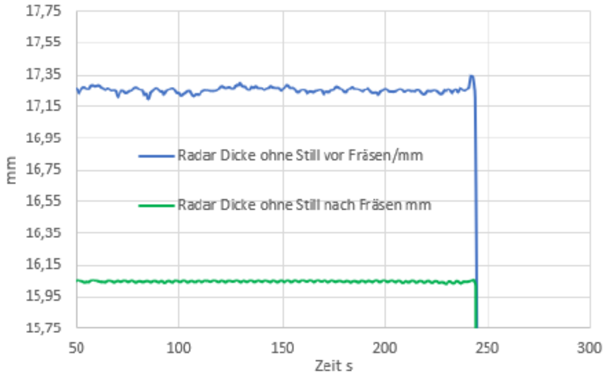
Errors induced by installation:
- movement of the measurement system
- changes in attachments / brackets (temperature/vibration)

Thickness & width cold material

Vergleichende Darstellung ohne Laservermessung:







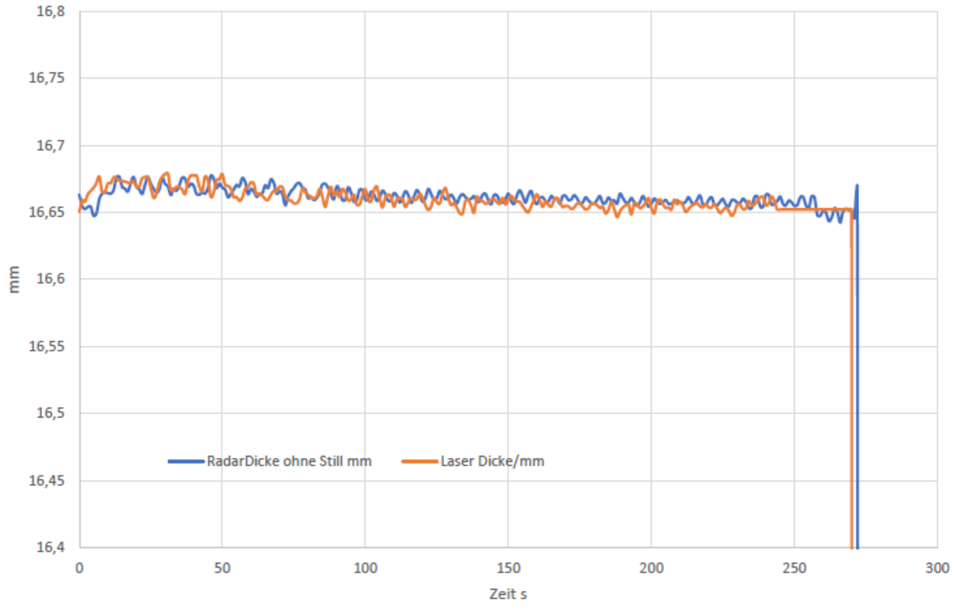
aus gleichem Zeitabschnitt

vor Fräsen Radar-Mittelwert =17,264 mm

nach Fräsen Radar-Mittelwert = 16,045 mm -> **vor/nach Fräsen Differenz 1,219 mm**

Thickness & width cold material

Vergleichende Darstellung

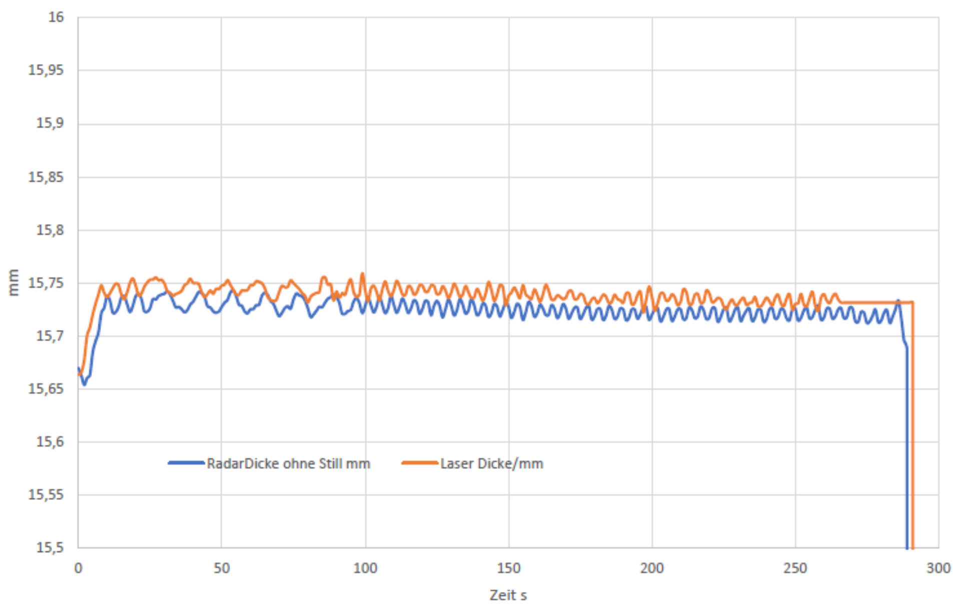


aus gleichem Zeitabschnitt : Radar-Mittelwert =16,661 mm; Standardabw. 0,0062 mm
Laser-Mittelwert = 16,660 mm; Standardabw. 0,0073 mm -> **Differenz 0,001 mm**

Berücksichtigung mit „Alu-Offsets“ 0,001 mm

Thickness & width cold material

Vergleichende Darstellung

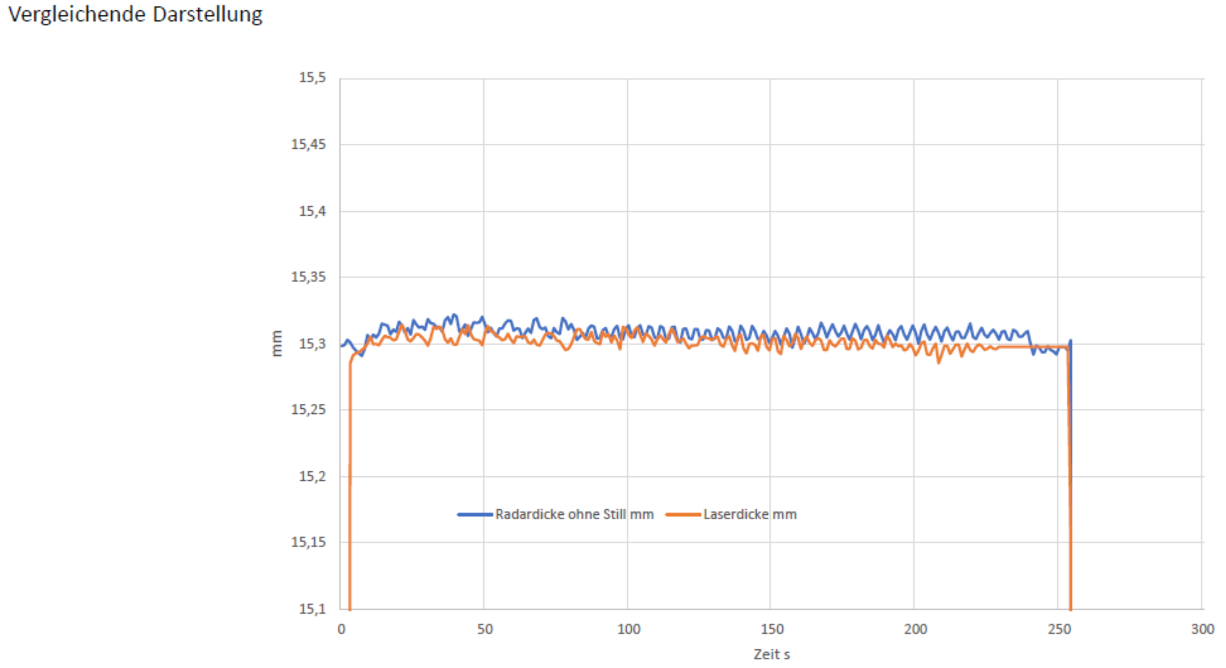


aus gleichem Zeitabschnitt

Radar-Mittelwert =15,724 mm; Standardabw. 0,0113 mm
Laser-Mittelwert = 15,739 mm ; Standardabw. 0,0107 mm -> **Differenz -0,015mm**

Berücksichtigung mit „Alu-Offsets“ -0,015 mm

Thickness & width cold material



aus gleichem Zeitabschnitt

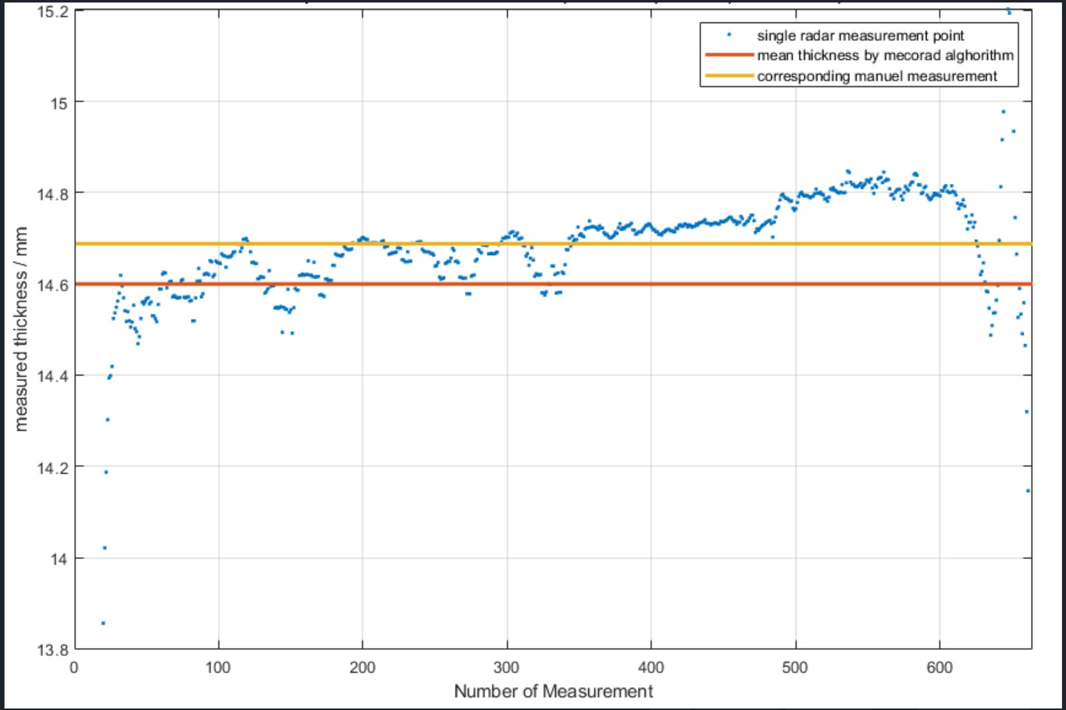
Radar-Mittelwert =15,308 mm; Standardabw. 0,0058 mm

Laser-Mittelwert = 15,302 mm; Standardabw. 0,0051 mm -> **Differenz 0,006 mm**

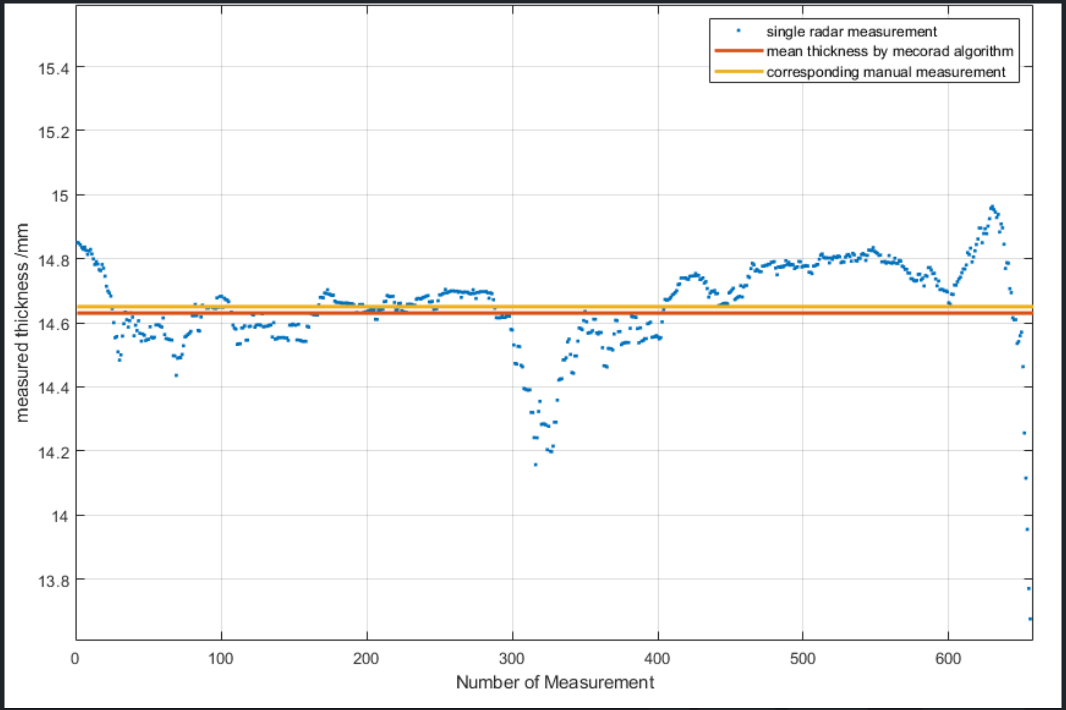
Berücksichtigung mit „Alu-Offsets“ 0,006 mm

Thickness & width in hot areas

Thickness gauging



Thickness gauging



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Summary

- Radar technology for metal applications made some huge leaps over the last few years
- The technology can handle difficult environments in all areas of metal production
- Radar is safe for workforce and environment
- The principle is not limited by material composition or thickness
- Temperature is an important topic but can be managed by compensation
- Radar is not limited to distancing tasks but will develop into material classification as well

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