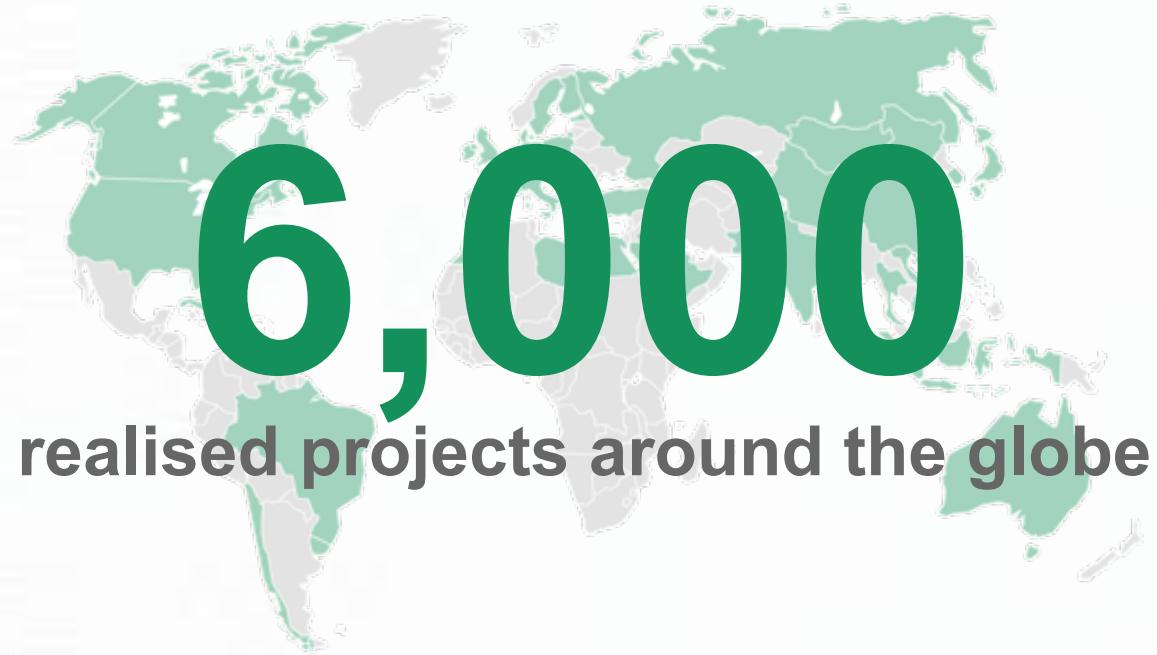




## Leichter gedacht, als gemacht – Lastmessungen in der Praxis

Eric Effer, windtest grevenbroich gmbh

# At a glance



**23** Years  
**Experience**

## Approved quality

- DAkkS ISO/IEC 17025
- MEASNET
- IECRE



Subsidiary  
in the  
**USA**  
since  
2014



**3**

## Test sites

Grevenbroich (GER)  
Lelystad (NLD)  
Iowa (USA)



# Eric Effern



- Dipl.-Ing. Elektrotechnik; RWTH Aachen
- **IECRE** convener Test labs
- IECRE assessor mech. loads, power performance, el. characteristics
- 1993 – 1997 ahu AG Wasser · Boden · Geomatik
- Seit 1997 windtest grevenbroich gmbh
- Seit 2006 **Bereichsleiter**  
**Technische Vermessungen**  
windtest grevenbroich gmbh
- Seit 2014 **Vice President**  
windtest north-america inc.
- Kontakt: +49 (0) 2181- 22 78 - 17  
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# International Rules and Regulations

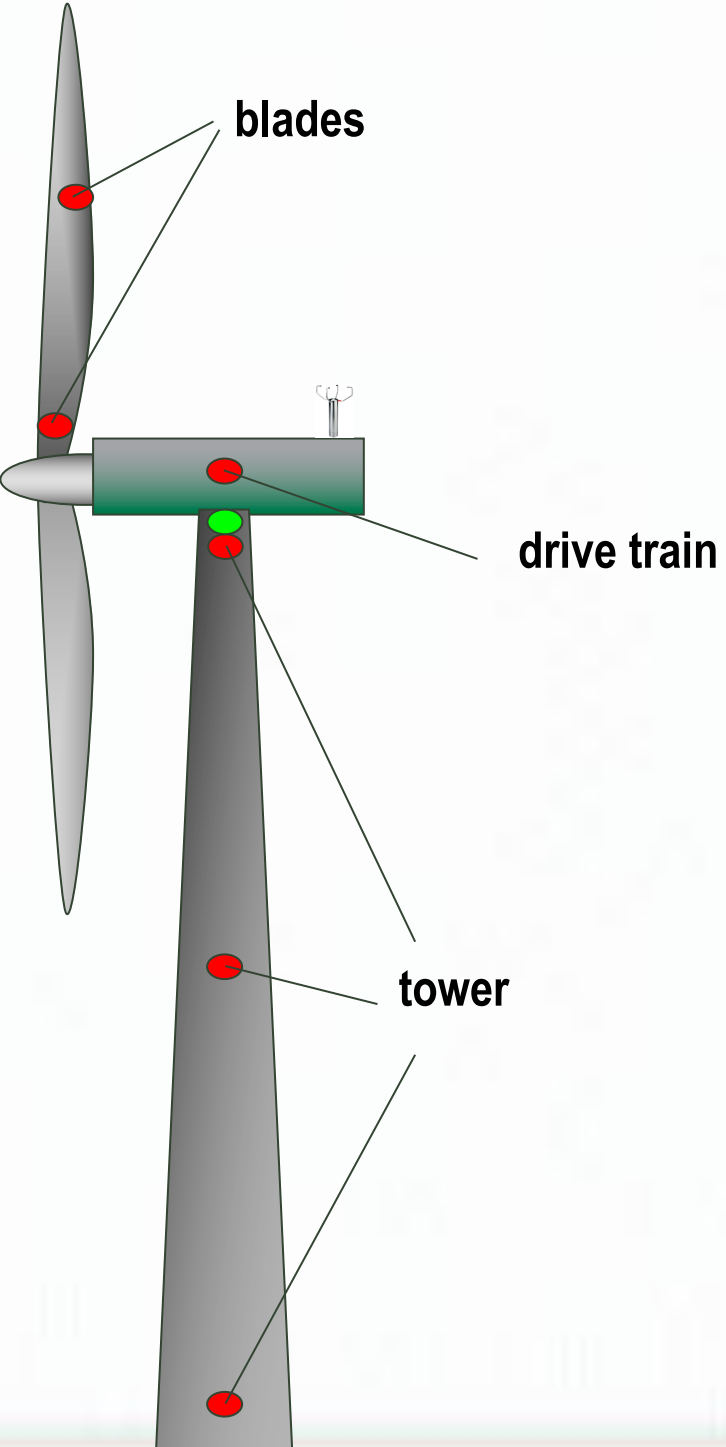
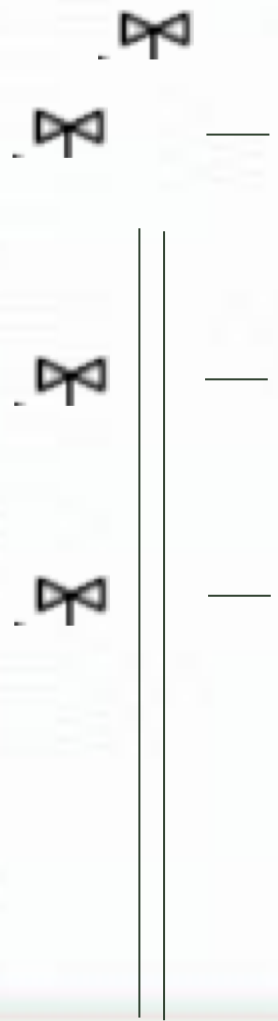
- IEC 61400 – 11           Acoustic noise measurement techniques
- IEC 41400 – 12 - 1       Power performance measurements with WMM  
Ed 1.0   2005  
Ed 2.0   2017
- IEC 61400 – 13           Measurement of mechanical loads  
TS       2001  
Ed 1.0   2015
- IEC 61400 – 21           Measurement of power quality
- Grid codes world wide
- Incentives world wide
- FGW TR
- VDI 3834
- ...

# Loads Quantities

## Ed 1.0

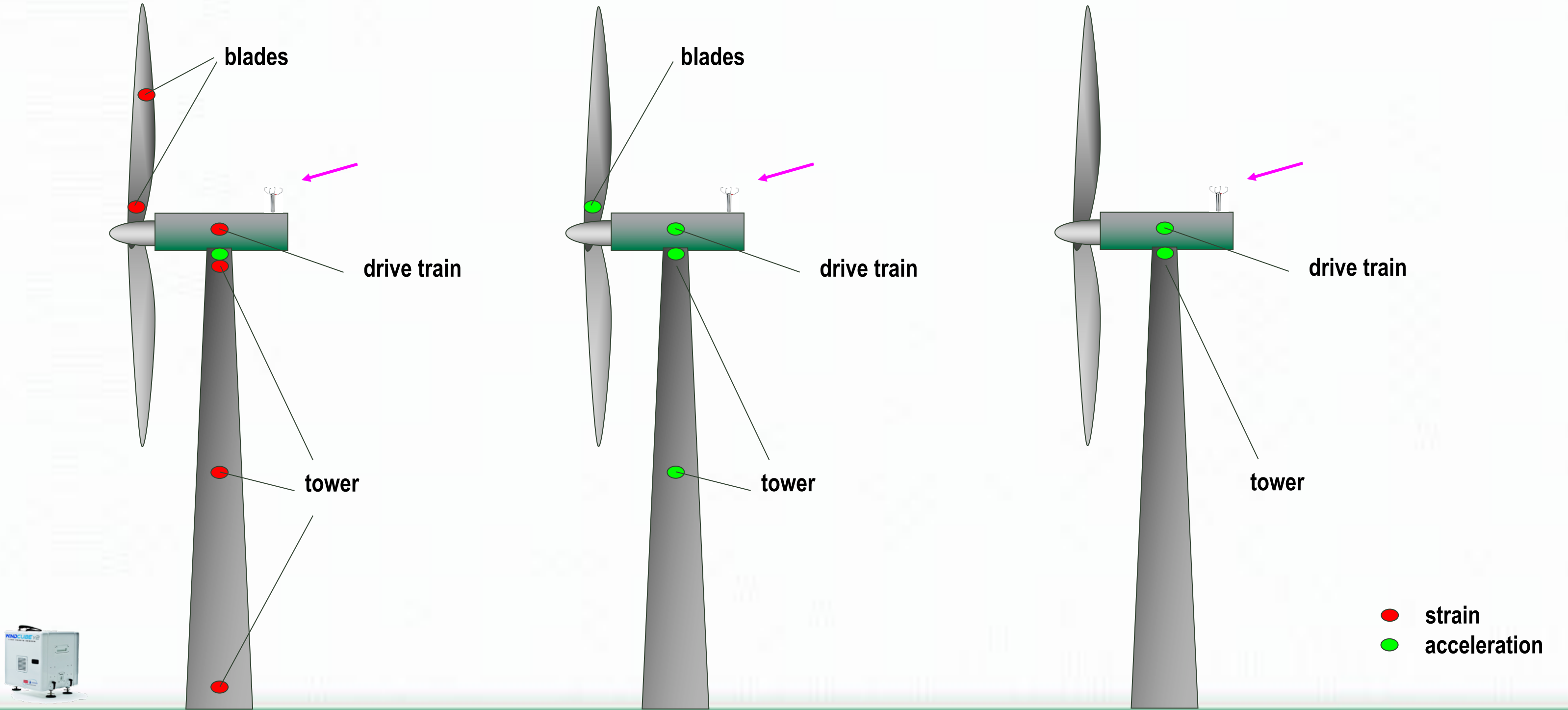
Position	Quantities to be measured	Turbine 1	Turbine 2 H > 1500 kW, D > 75m
Tower Base	Bending Moment 2x	yes	yes
Tower Mid	Bending Moment 2x	no	recommended
Tower Top	Bending Moment 2x Torsion acceleration 2x	no no no	yes yes yes/no
Rotor	Bending Moment 2x Torsion	yes yes	yes yes
Blades Root	Bending Moment 2x Torsion Pitch actuation	Yes (1), recommended 2) no no	Yes (2), recommended (3) recommended yes (1)
Blades Distribution	Bending Moment 2x	no	Yes (2), recommended (3)

# Measurement Positions



● strain  
● acceleration

# Measurement Positions



# Acceleration to Strain

**Strain**  $\varepsilon = \frac{\Delta l}{l} = E \sin(\omega t)$

**Acc.**  $a = A \sin(\omega t)$

**Velocity**  $v = \int a \cdot dt = -\frac{A}{\omega} \cos(\omega t)$

**Strain**  $\varepsilon = \int v \cdot dt = \frac{A}{\omega^2} \sin(\omega t)$



# Acceleration to Strain

**Strain**  $\varepsilon = \frac{\Delta l}{l} = E \sin(\varpi t)$

**Acc.**  $a = A \sin(\varpi t) + C$

**Velocity**  $v = \int a \cdot dt = -\frac{A}{\varpi} \cos(\varpi t) + Ct$

**Strain**  $\varepsilon = \int v \cdot dt = \frac{A}{\varpi^2} \sin(\varpi t) + \frac{C}{2} t^2$

**Acc.**  $a = \sum_i A_i \sin(\varpi_i t) + \sum_i C_i$

# Vibration Measurement



Abbildung 5-3: Messposition Turm oben



Abbildung 5-5: Messposition Generatorunterseite



Abbildung 5-1: Messposition Generatorseitenwand

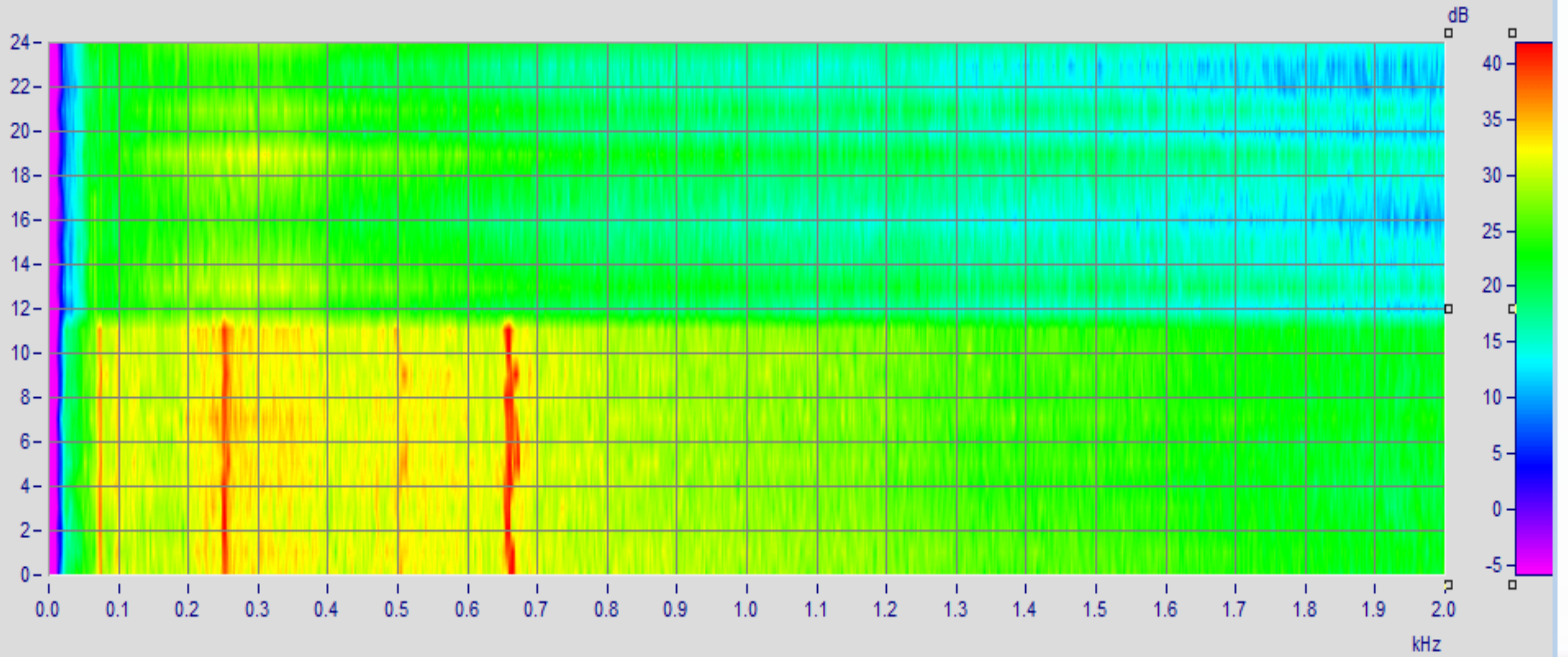


Abbildung 5-4: Drehzahlmessung

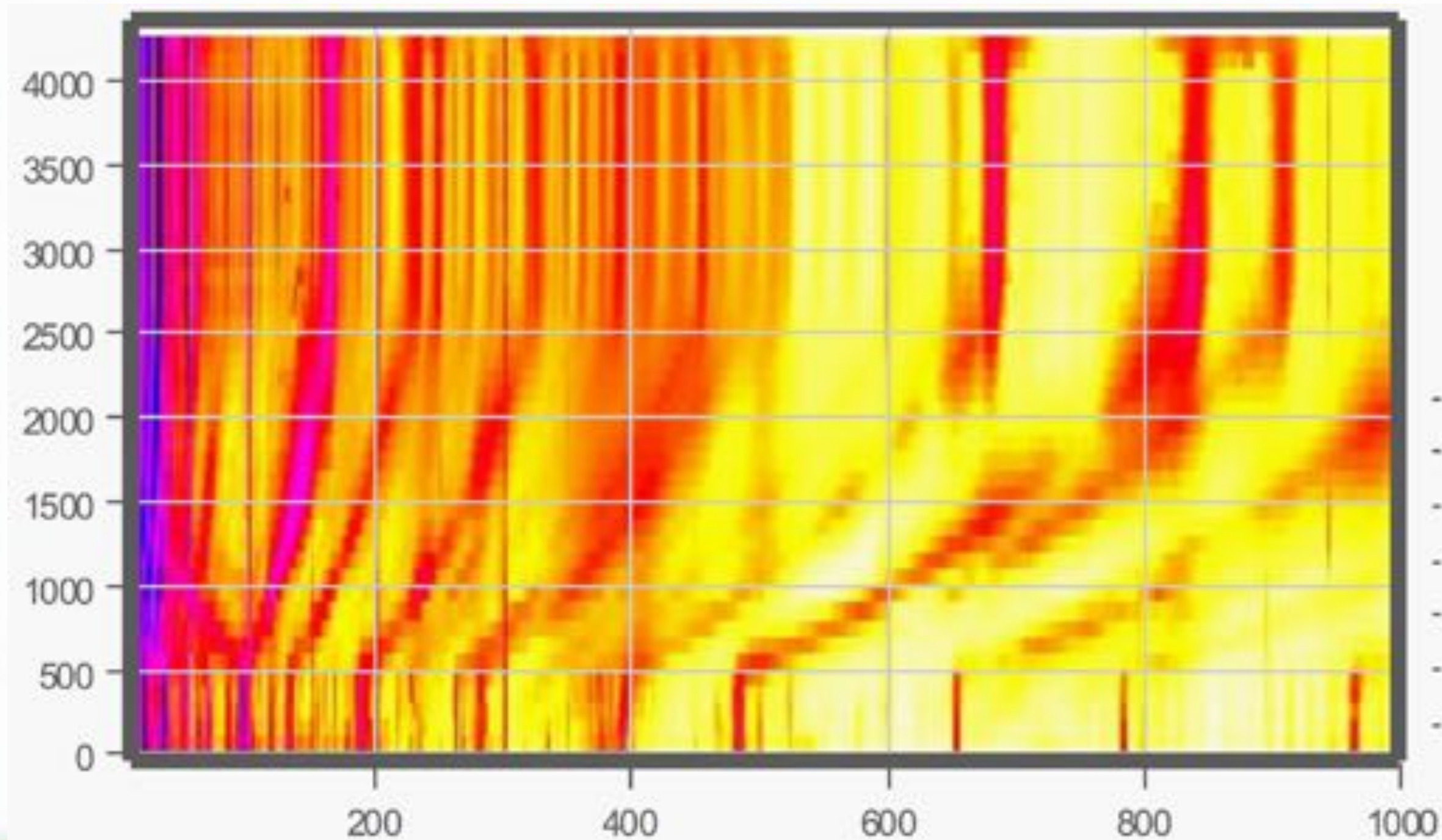


Abbildung 5-2: Messposition Maschinenträger

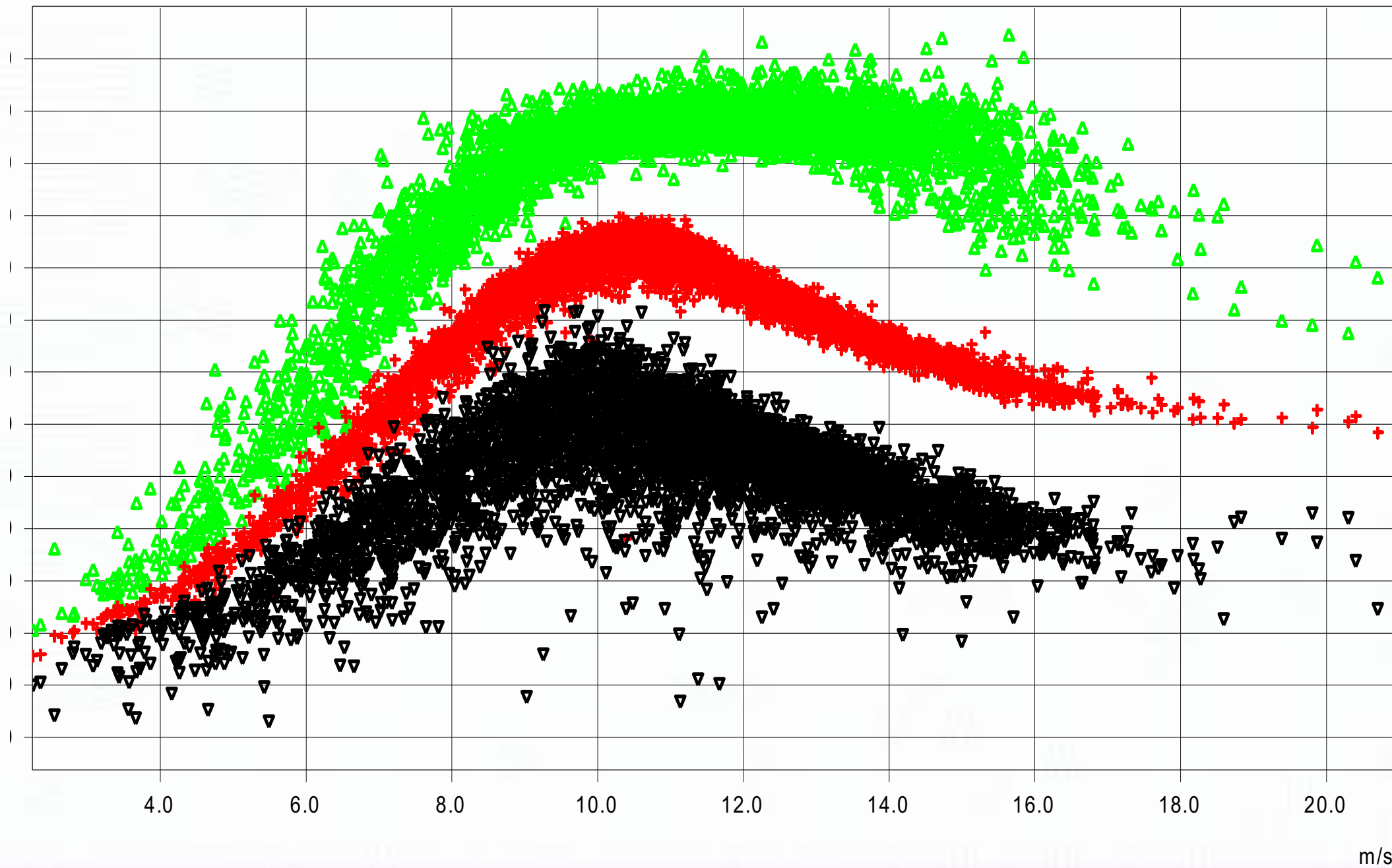
# Vibration Analysis



# Vibration Analysis



# Tower Loads vs Wind Speed



# LZV

## Betriebsdaten

- Schnittstellen Betriebsdaten: Leistung, Windgeschwindigkeit, Windrichtung, Drehzahl, Azimut Position, Pitch Winkel
- Szenarien

### Digitale Bus Daten

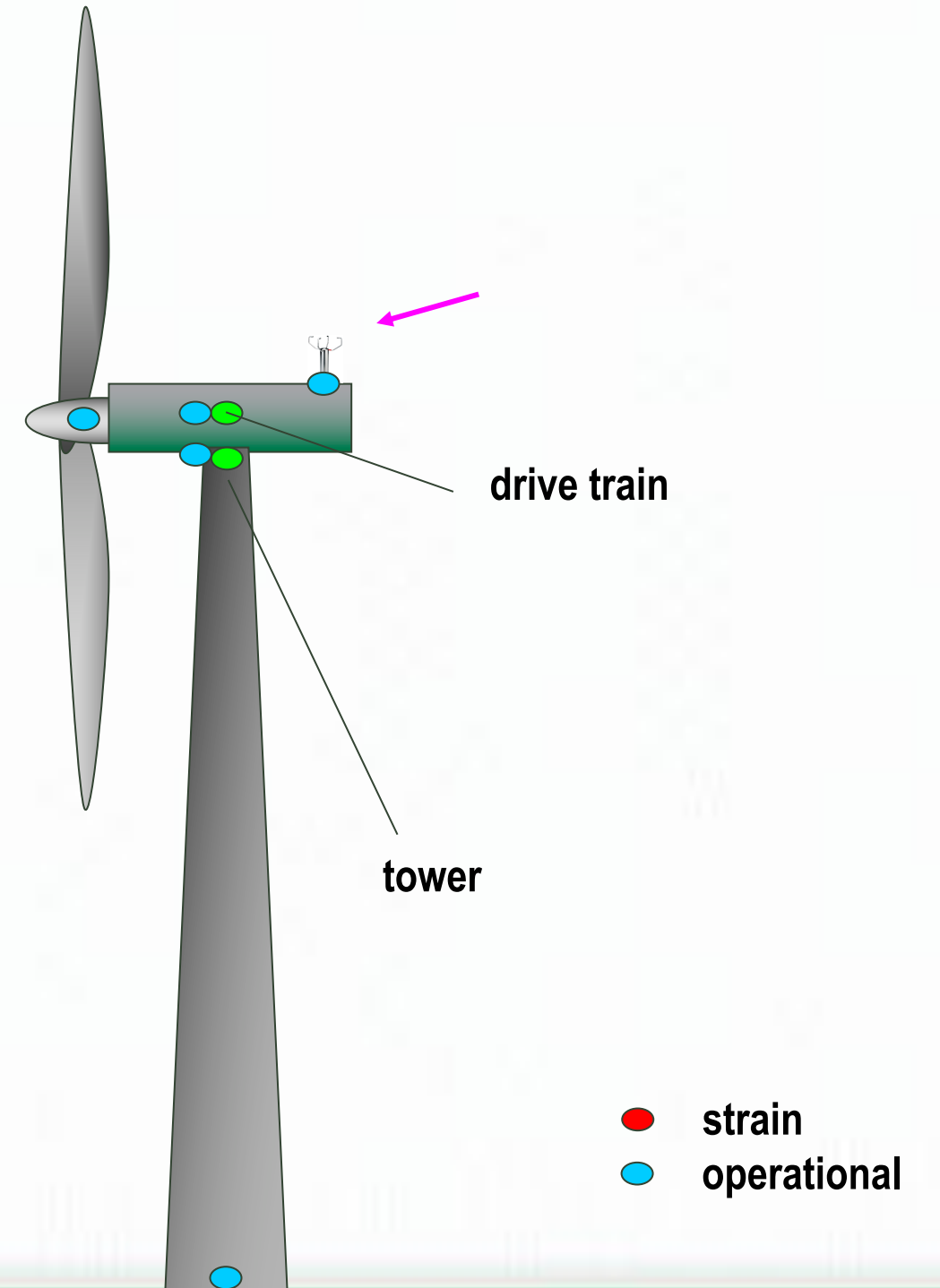
Analoges Interface (Kalibrierung, Zuordnung, ...)

nur File basiert (Abtastrate, Zeitsynchronisation)

vollständige / keine / falsche Dokumentation

kein Zugriff

### Eigene Messung



# Messsystem



- flexibel
- beliebig kombinierbar
- robust
- Remote control

*Thank you for your attention!*



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